Canadian Manuscript Report of
Fisheries and Aquatic Sciences 2988

2012

REVIEW OF THE GEORGES BANK RESEARCH VESSEL SURVEY PROGRAM, 1987-2011

by

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Cat. No. Fs 97-4/0000E ISSN 1488-5387 (online version)
Cat. No. Fs 97-4/0000E ISSN 0706-6473 (print version)

Correct citation for this publication:

Stone H.H. and Gross, W.E. 2012. Review of the Georges Bank Research Vessel Survey Program, 1987-2011. Can. Manuscr. Rep. Fish. Aquat. Sci. 2988: xiii + 95p.

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ABSTRACT

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The Canadian Department of Fisheries and Oceans has conducted annual multi-species bottom trawl surveys on Georges Bank (statistical unit areas 5Zj, 5Zm, 5Zh, 5Zn, 5Zg, and 5Zo) during February/March since 1987. The survey follows a stratified random sampling design for tow locations with eight designated strata and includes observations of marine fish and invertebrate species caught as well as hydrographic sampling of the water column. This report summarizes the data available for selected marine fish and invertebrate species captured during the Georges Bank surveys. Plots of geographic distribution, biomass trends and stratified length frequency are presented for the major commercial fish and invertebrate species as well as for species that comprise a large part of the survey catch (i.e. species which occur in more than 10% of all sets from 1987-2011). For cod, haddock, pollock and yellowtail flounder, which have individual fish weights and maturity stage data collected throughout most of the time series, trends in condition (Fulton's K; weight/length^3) and maturity were also reported. Temporal patterns in hydrographic conditions are illustrated by plots of bottom temperature and salinity by strata from 1987 to 2011. Data collected from this survey are useful for monitoring temporal and spatial trends in the distribution, abundance and biomass for a number of fish and invertebrate species and for monitoring temporal and spatial variability in hydrographic conditions across the bank. In addition, the data provide a primary source of information that can further our understanding of long term changes in the species composition and biodiversity of the Georges Bank ecosystem. The survey data are available on the Maritimes Regional Ecosystem Survey database for more detailed analyses.

RÉSUMÉ

Stone, H.H. et Gross, W.E. 2012. Review of the Georges Bank Research Vessel Survey Program, 1987-2011. Can. Manuscr. Rep. Fish. Aquat. Sci. 2988: xiii + 95 p.

Pêches et Océans Canada réalise annuellement des relevés plurispécifiques au chalut de fond dans le banc de Georges (unités statistiques 5Zj, 5Zm, 5Zh, 5Zn, 5Zg, et 5Zo) pendant les mois de février à mars, et ce, depuis 1987. Le relevé respecte un modèle d'échantillonnage aléatoire stratifié pour deux emplacements comprenant huit strates désignées et comprend des observations d'espèces invertébrées et de poissons marins capturés, de même que des observations de l'échantillonnage hydrographique de la colonne d'eau. Le présent rapport résume les données accessibles pour les espèces invertébrées et les poissons marins capturés pendant les relevés effectués dans le banc de Georges. Certains graphiques illustrant la répartition géographique, les tendances de la biomasse et la fréquence de longueur stratifiée sont présentés pour les principaux poissons et espèces invertébrées commerciaux, de même que pour les espèces qui représentent une grande partie des prises du relevé (c.-à-d. les espèces qui ont été observées dans plus de 10 % de tous les traits de chalut de 1987 à 2011). Dans les cas de la morue, de l'aiglefin, de la goberge et de la limande à queue jaune, pour qui les données sur le poids et sur les stades de maturité sont rassemblées individuellement dans la plupart des séries chronologiques, on a également rendu compte des tendances relatives à leur condition (coefficient de condition de Fulton, soit poids/longueur^3) et à leur maturité. Les tendances temporelles des conditions hydrographiques sont illustrées à l'aide de graphiques indiquant la température de fond et la salinité par strate de 1987 à 2011. Les données rassemblées à partir de ce relevé sont utiles à la surveillance des tendances temporelles et spatiales de la répartition, de l'abondance et de la biomasse pour un certain nombre d'espèces invertébrées et de poissons, tout en aidant à la surveillance de la variabilité temporelle et spatiale des conditions hydrographiques à l'échelle du banc. En outre, les données offrent une source principale d'information qui permet d'approfondir notre compréhension des changements à long terme en matière de composition des espèces et de biodiversité dans l'écosystème du banc de Georges. Il est possible de consulter les données du relevé et des analyses plus détaillées à partir de la base de données du relevé sur l'écosystème régional des Maritimes.

INTRODUCTION

The Canadian Department of Fisheries and Oceans (DFO) has conducted annual (February/March) multi-species bottom trawl surveys on Georges Bank since 1987 with the objective of providing an assessment of the state of marine resources and environmental conditions in statistical unit areas 5Zj, 5Zm, 5Zh, 5Zn, 5Zg, and 5Zo (Figure 1). The survey follows a stratified random sampling design for tow location and includes observations of marine fish and invertebrate species caught as well as hydrographic sampling of the water column. Stratum boundaries are generally based on depth contours as well as the location of the international boundary and geographic regions on the bank. The stratified random sampling design serves a number of purposes. It allows the station locations to be spread over the entire area, provides differential sampling intensity among strata and facilitates analyses over various geographic regions corresponding to different stock or management definitions.

Currently, the data collected from this survey is principally used in stock assessments conducted by the Transboundary Resources Assessment Committee (TRAC) for monitoring trends in distribution, abundance and biomass for shared resources of cod, haddock and yellowtail flounder across the Canada/USA boundary in the Gulf of Maine-Georges Bank region (Legault *et al.* 2011, Van Eeckhaute and Brooks 2010, Wang *et al.* 2011). Since the DFO survey collects information for a wide range of species caught, there is added potential for long term monitoring of several non-commercial species, some of which may be bycatch in directed fisheries (Gavaris *et al.* 2010) or that may be of interest under the Species at Risk Act (SARA) or to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). In addition, the survey provides data to the Atlantic Zonal Monitoring Program (AZMP) for monitoring temporal and spatial variability in hydrographic conditions across the bank. Spring and fall research vessel (RV) surveys have also been conducted annually on Georges Bank by the US National Marine Fisheries Service (NMFS) since the 1960s. Although these surveys also provide information on trends in abundance and biomass for several fish and invertebrate species, they are not discussed in this document which focuses solely on DFO survey findings from 1987-2011.

This report summarizes the data available for selected marine fish and invertebrate species captured from the Georges Bank survey and is complementary to the Scotian Shelf Summer Survey Report Series (i.e. Clark *et al.* 2010). Plots of geographic distribution (1987-2011), biomass trends (1987-2011) and stratified length frequency (2010 and 2011 *vs* the long term median for 1987-2009 (finfish) or 2006-2009 (invertebrate) are presented for the major commercial fish and invertebrate species as well as for species that comprise a large part of the survey catch; i.e. species which occur in more than 10% of all sets from 1987-2011. The species examined were restricted in this manner to avoid rare species for which catches display high inter-annual variability. For

cod, haddock, pollock and yellowtail flounder, which have individual fish weights and maturity stage data collected throughout most of the time series, trends in condition (Fulton's K; weight/length^3) and maturity were also reported. Temporal patterns in hydrographic conditions are illustrated by plots of bottom temperature and salinity by strata from 1987 to 2011.

METHODS

SURVEY VESSELS AND TRAWL DEPLOYMENT

The main vessel used for the Georges Bank survey program was the research trawler CCGS *Alfred Needler*. During years when the *Alfred Needler* was unavailable (1993, 2004, 2007, 2008), the sister ship, CCGS *Wilfred Templeman,* was used as a replacement. Since both vessels were considered to be identical, no conversion factors for "vessel effect" have been developed for adjusting the time series of *Templeman* catches to *Needler* equivalents. In 2005 and 2006, a comparative fishing experiment was carried out during the regular Georges Bank survey program using the *Alfred Needler* and the CCGS *Teleost*. At the time it was thought that the *Needler* might eventually be replaced by the *Teleost*, or that the latter could be substituted when mechanical breakdowns occurred on the *Needler*. No conversion factors were developed to adjust species-specific catches between vessels and the *Needler* has continued to be the primary survey platform.

Bottom trawl survey protocols involved conducting a standard 30 minute tow using a Western IIA net with a 20 mm stretched mesh cod-end liner at a speed of 3.5 knots at each station (Koeller 1981). Tow duration could be shortened when rough bottom was encountered, but tows of less than 20 minutes were not considered valid. When necessary, alternate fishing stations were substituted for primary and secondary stations depending on circumstances (i.e. untrawlable bottom, presence of fixed gear). During most surveys, the amount of warp deployed was determined by the officer on the bridge, based on fishing experience. In general, a warp-to-depth ratio of about 3:1 was used in shallow water, with a lower ratio used in deeper water or on rough bottom. Since 2005, a warp-to-depth ratio table developed for the Western IIA trawl has been used to determine the amount of warp deployed for each set based on the bottom depth at each station. For the depths of strata 5Z1-5Z8, the designated warp-to-depth ratio remained about 3:1.

SURVEY STRATA, STATION SELECTION AND STATION ALLOCATION

The Georges Bank survey was originally planned to principally provide age-specific abundance trends for groundfish species, in particular cod and haddock.

A DFO survey of Georges Bank was initially conducted in 1986 (Gavaris and Waiwood 1986) and included coverage in deeper waters all around the edge of the bank (Figure 2). Low catches of cod and haddock were observed in these deeper waters. Examination of NMFS spring survey data confirmed that catches of cod and haddock in these deeper waters was spotty and highly variable during spring. Further, the area of deeper water was considerable, consuming a great deal of the available time for conduct of the survey while providing limited useful information. Accordingly, the area of coverage of the bank was restricted to depths up to 183 m in 1987 (Gavaris 1987). Stratum boundaries were repositioned to reflect the location of the Canada/USA international boundary and the area of coverage on the bank was expanded west towards Cape Cod and the Nantucket Shoals. Consequently, data from the 1986 DFO survey has not been included in any of the analyses in this document, however, age specific indices of abundance calculated from the 1986 DFO survey are included in TRAC assessments for cod and haddock (Wang *et al.* 2011, Van Eeckhaute and Brooks 2010).

The survey stratification scheme from 1987 to 2010 includes 8 strata, with stratum 5Z1 and 5Z2 in Canadian waters and the remaining strata, 5Z3-5Z8, extending west in USA waters to Cape Cod, Massachusetts (Figure 1). Stratum depth ranges are < 93 m (50 fm), 0-183 m (0-100 fm), and 93-183 m (51-100 fm). The number of primary and secondary set allocations, depth ranges, trawlable units and square nautical miles (area) differ for each stratum and are summarized in Table 1. Surveys were generally scheduled from mid-February to mid-March when resident cod and haddock are aggregated at shallower depths on Georges Bank (coincidentally overlapping with their spawning periods). Over the time series, the surveys either occurred entirely in February or March, or they began in February and ended in March (Table 2).

In 2010, a new stratum (5Z9) was added to the Georges Bank survey design for depths > 183 m in Canadian waters along the northeastern part of the bank (5Zj) (Fig. 1). Since this new stratum has only been sampled for two years, data from 5Z9 has not been included in any of the analyses in this document but there are plans to consider this stratum in future assessments for cod and haddock once the time series is long enough.

A computer program was used to randomly generate station locations (latitude and longitude) for the stratified random stations (primary, secondary and alternate) to be sampled in a given year based on the set allocation scheme for each stratum (Table 1). Stations were chosen randomly from a computer file which contained the coordinates of the centers of 2.0 x 2.5 minute rectangles of latitude and longitude within each stratum. Regions with untrawlable bottom in strata 5Z3 (Georges Shoal, Little Georges Shoal) and 5Z6/5Z7 (Cultivator Shoal) were excluded from the set selection process. Sampling density of primary stations was initially based on one station per 100 square nautical miles with the aim of providing sampling intensity proportional to area. Secondary stations were

used to increase sampling intensity in strata where fish abundance, and thereby catch variance, was higher. The initial allocation of secondary stations was based on evaluation of cod and haddock densities observed during NMFS spring surveys. In 1992, stations were redistributed based on revised estimates of variability from cod and haddock catches observed during previous DFO surveys and the total set allocation for the survey dropped from 140 to 100 stations due to a reduction in available sea days for the survey program. Strata 5Z1 and 5Z2, which typically have higher catches of cod and haddock (and consequently higher catch variability) were sampled at a higher density than all other strata. Strata 5Z3 and 5Z4 were also allocated some additional stations to augment the "proportional to area allocation", but not as many as 5Z1 and 5Z2. Therefore, the allocation of stations to strata was not directly in proportion to stratum area.

SAMPLING PROTOCOLS OF BOTTOM TRAWL CATCH

The Georges Bank survey follows operational and sampling protocols which are nearly identical to those used for DFO surveys in the southern Gulf of St. Lawrence (Hurlbut and Clay 1990) and the Scotian Shelf/Bay of Fundy region (Koeller 1981; M. Strong and S. Gavaris, DFO Maritimes Region, Manual for Marine Bottom Trawl Surveys, Scotia-Fundy Region, unpublished manuscript). The catch from each set was sorted by species into baskets which were weighed and then biological data was collected on individual fish and selected invertebrate species. All fish caught were identified to the species level; when identification was not possible at sea, unidentified species were frozen and brought ashore for positive identification.

For all fish species (since 1987) and invertebrate species (lobster and squid since 1987, sea scallop since 2000 and other invertebrate species since 2007), the total number and total weight (kg) caught was recorded from all successful tows. The only invertebrate species that were consistently identified and enumerated in this survey since 1987 were short-fin squid and lobster. Length frequencies were collected for all fish (1987 onwards; generally fork length but total length for skates and dogfish; cm), mantle length for squid (1987 onwards; cm), carapace width for crabs (2006 onwards; mm), carapace length for lobsters (2006 onwards; mm) and shell height for sea scallop (2006 onwards; mm) from all successful sets according to instructions in the Manual for Groundfish Bottom Trawl Surveys in the Maritimes Region (B. Hatt and D. Clark, Biological Station, St. Andrews NB, pers. comm).

The total catch weight of each species was accurate to ± 1 kg from 1987-1995 when spring balances were used. Total catches of a species that were less than 0.5 kg were recorded as zero. From 1996 onwards when electronic balances with finer precision became available, the precision increased to ± 0.01 kg. The total catch of each species was weighed for most sets, but when necessary, large catches were subsampled and then pro-rated to total weight and total

number using a simple ratio estimator (i.e. baskets sampled/baskets caught, weight sampled/weight caught, numbers sampled/numbers caught).

Over the past decade, there have been a few changes in the biological data collection protocols for fish caught during the Georges Bank survey. Prior to 2007, individual fish weights were collected for only cod, haddock, pollock and yellowtail flounder, with no weights recorded for yellowtail flounder from 1992-1995. From 2007 on, the practise of recording individual fish weights has been applied to all fish and invertebrate species. For most species, survey indices are considered to be proportional to abundance, however, catches of pelagic, schooling species such as herring and mackerel may not reflect abundance trends. For these species, other biological information, such as length and weight are still relevant and are available on the Maritimes Regional Ecosystem Survey database.

Length stratified samples for individual fish weights (g) were obtained at the level of one per one centimeter interval (by sex if required) for most species, 3 per 3 cm for cod and pollock, and 2 per 2 cm interval for haddock. From 1987-1992 spring scales were used to weigh individual fish and were accurate to ± 25 g; weights less than 25 g were not recorded. Electronic balances accurate to ± 5 g and ± 2 g were introduced in 1993 and were used up to 2010, after which electronic balances accurate to ± 1 g were used.

Mantle length (squid) and carapace length (lobster) measurements are available back to 1987 and 2006, respectively, while individual weights (1 per 1 cm grouping for squid, 1 per 1 mm grouping for lobster) are available from 2007 onwards. For other invertebrate species (i.e. sea scallop, crabs), individual lengths and weights (1 per 1 cm grouping) are available from 2007-2008 onwards. The practice of recording individual weights for lobsters and crabs will be discontinued from 2012 onwards since individuals that are missing or regenerating claws add error to individual weight measurements.

Over the time series (1987-2011), otolith samples for age determinations were collected from cod (n = 17,016), haddock (n = 24,675) and pollock (n = 2,323) and since 2007 from white hake (n = 38), cusk (n = 4) and halibut (n = 10) (Table 3). Yellowtail flounder were sampled for otoliths from 1987-1991 and 1996-2003 (n = 7,905), and for scales from 2004 to present (n = 3,793). Cod, haddock and pollock otoliths were sectioned and aged at the St. Andrews Biological Station (SABS) using the methodology of Strong *et al.* (1985). For yellowtail flounder, there has been an arrangement in place since 2004 with the NMFS Northeast Fisheries Science Centre in Woods Hole to provide age determinations from scale samples collected during the survey using the methodology of Penttila (1988). Scales are the preferred structure for aging Georges Bank yellowtail flounder since age determination using otolith thin sections was found to be hampered by the presence of weak, diffuse or split opaque zones and strong checks, which made the interpretation of annuli subjective and difficult (Stone

and Perley 2002). Aging material for cod, haddock, pollock and yellowtail flounder is stored at SABS, while material from cusk, white hake and halibut is stored at the Bedford Institute of Oceanography (BIO) in Dartmouth, NS.

Maturity stages were routinely assigned to cod, haddock and pollock using a Groundfish Maturity Schedule which generally followed the classification of Kesteven (1960) (Table 4). For these species, maturity data was available throughout the time series (Table 5). Maturities were taken for yellowtail flounder at different times during the survey program (i.e. 1987-1991, 1997, 1999, 2003) and more recently (since 2007) for white hake, halibut and cusk. In the case of silver hake, maturities were collected in 1989 and 1990 as part of a special sampling request.

All sampling and set information was initially recorded at sea on paper forms (1987-1994). Once the survey was completed, the data was key-punched, uploaded to electronic files and then edited before it was ready for any analyses, a process which took up to 3 months to complete. With the development of an Oracle-based data entry system in 1994 (called the Groundfish Surveys at sea Entry system or GSE), all data was entered directly into a database with online data editing and automatic error checking based on predefined criteria. This innovation meant that data could be available for analysis within one week of the survey.

HYDROGRAPHIC OBSERVATIONS

Hydrographic sampling was initially conducted at all fishing stations across the bank from 1987-1998 with a Conductivity (salinity), Temperature and Depth (CTD) meter fitted on a Carousel Rosette. In 1999, sampling was reduced to about one half the total compliment of fishing stations allocated in a given year (see Table 11). At these stations, depth profiles of temperature and conductivity (salinity) were obtained with a SBE-25 Conductivity, Temperature and Depth (CTD) meter deployed from a winch fitted with a metre block and Niskin bottles were deployed manually to collect water samples at the bottom and near the surface. Additional instruments were added to the CTD instrumentation package in 1999 to measure oxygen concentration, fluorescence and irradiance (PAR extinction); this is also when the AZMP took over the responsibility for all hydrographic sampling data collection. In 2009, the CTD package was fitted on a Carousel Rosette deployed by the *Alfred Needler*. (Note: Prior to 2009, hydrographic sampling used the CTD instrumentation package without the carousel on both the *Needler* and the *Templeman*). Niskin bottles attached to the Rosette collected water from the bottom and from 5 m (near surface) for the following sampling:

- 5 m: salinity (x1), nutrients (x2), chlorophyll-a (x2) and oxygen determination (x2),

- Bottom: salinity (x1), nutrients (x2), chlorophyll-a (x2) and oxygen determination (x2).

Oxygen measurements were performed after the CTD cast using an ORION 842 bench meter. Salinity determinations (parts per thousand, ppt) were made using a Guildline 'Portasal' salinometer. Chlorophyll-a samples were processed onboard with a Turner-Designs fluorometer. Surface temperatures were measured using a VEMCO SEATEMP temperature probe. VEMCO depth/temperature miniloggers were attached to the trawl to monitor bottom water/fishing depth temperature. At selected stations, vertical zooplankton tows were made from bottom to surface using a 0.5 m diameter ring net with 202 μ mesh. Bottom temperature (^{o}C) and salinity (ppt) data has been summarized in this document for comparisons across strata.

Representative profiles of temperature (^{o}C), salinity (ppt), chlorophyll concentration (ug/l) and oxygen level (ml/l) are illustrated for a CTD cast in shallow water (80 m) on top of the bank in stratum 5Z2 (Figure 3, upper panel) and for a cast in deeper water (250 m) along the edge of the bank in Stratum 5Z1 (Figure 3, lower panel). Both profiles were obtained near Corsair Canyon in February 2011 and indicate complete mixing vertically on top of the bank with lower temperature and salinity compared to the stratified profile from the edge of the bank which is characterized by warmer bottom water with higher salinity.

DATA ANALYSES

Only successfully completed stratified random tows (experiment type = 1) were used in the analyses of species distribution, total biomass and abundance at size. The distance of each successful tow was adjusted to a standard length of 1.75 nautical miles which was then used in calculations of stratified total biomass and stratified length frequencies as described in Halliday and Koeller (1980) for the selected species presented in this document. The stratified total abundance at length for the two most recent survey years (2010 and 2011) was then compared to the long term median (50th percentile) for 1987-2009 (finfish) or 2006-2009 (invertebrates). The long term median was used for these comparisons since it was considered to be a useful measure of central tendency representing the value at which 50% of the observations were above and 50% were below. For some fish species discussed in this document (i.e. redfish, cusk, Atlantic wolfish, white hake and monkfish, smooth skate) there were too few length measurements available over the survey time series to allow for meaningful comparisons of recent trends in abundance at size with the long term median.

The survey protocol required the completion of all primary set locations and most secondary set locations for strata 5Z1-5Z4. These strata are essential for the TRAC assessments and the sharing formula used in calculations of Total

Allowable Catches (TACs) for transboundary stocks (Murawski and Gavaris 2004). Although the western strata (5Z5-5Z8) were also considered important, in some years sampling was either incomplete or greatly reduced (i.e. 1993, 1994, 2006, 2007, 2009 and 2010; Table 5) due to inclement weather or mechanical problems with the survey vessel which reduced available sea time to complete fishing. For continuity of the time series, analyses of temporal trends in total biomass and stratified length frequencies were based on strata 5Z1-5Z4, while geographic distribution plots (6 or 7-yr average weight (kg)/tow aggregated by 5 minute rectangles of latitude and longitude), data summaries in tables, and analyses of trends in maturity and condition factor, generally used data from all survey strata (5Z1-5Z8).

Trends in condition (Fulton's K; weight/length^3) were examined for cod, haddock, pollock and yellowtail flounder, all of which had individual fish weights recorded for most of the time series (note: no weights were recorded for yellowtail flounder from 1992-1995). Scatter plots of condition at size were used to determine the appropriate length ranges for this analysis (i.e. where there was no change in condition at size). Length ranges were 30-80 cm for cod and pollock, 30-70 cm for haddock and 25-40 cm for yellowtail flounder.

Maturity stage observations for cod, haddock, pollock and yellowtail flounder were grouped by strata (5Z1-5Z8) for comparisons of spatial differences in the predominant maturity stages. Temporal differences in length at 50% maturity were also examined for cod and haddock based on proportion mature at size (where mature fish were defined as stages 2-8; Table 3). For this analysis, the data was grouped into 5 year blocks for strata 5Z1-5Z4 combined to determine if any changes had occurred over the 25 year time series. Only cod and haddock were examined since annual sample sizes were not large enough to examine trends for other species. This analysis was based on sampled fish and was not scaled to population level.

RESULTS

SURVEY BIOMASS, SPECIES COMPOSITION AND AGE SAMPLING

A total of 2,267 fishing stations were successfully completed from 1987 to 2011, ranging from a high of 132 sets in 1988 and 1991 to a low of 63 sets in 2010 (mean $_{(1987\text{-}2011)}$ = 85 sets/yr) (Table 6). In some years, more than 100 stations were completed due to the increased allocation of sets to strata from1988 to1991 (i.e. total compliment was 140 sets for 1988-1991 *vs* 100 sets from 1992 onwards) and additional tows conducted during the 2005 comparative fishing experiment. On average, 83-95% of allocated sets were completed in strata 5Z1-5Z4 from 1992 onwards, compared to 76-82% for strata 5Z5-5Z8. This pattern

generally reflects the higher priority for sampling strata 5Z1-5Z4 due to their importance in the TRAC assessments.

Trends in total biomass for each of the eight strata show a high degree of variability with concurrence in peak biomass across strata in some years but not in others (Figure 4). In any given year, the high estimates of total biomass within strata (year effects) were influenced by catches of one or more species. For example, the very high biomass estimates in 5Z8 during the late 1980s to early 1990s was influenced by large catches of spiny dogfish. In stratum 5Z1, peaks in 1992 and 1994 were attributed to high catches of dogfish while peaks in 2008 and 2009 resulted from very large sets of yellowtail flounder. Stratum 5Z5 exhibited peaks in 1998 and 2001 due to large catches of mackerel, and the peaks in 5Z2 in 2003 and 2004 were due to large catches of haddock.

Over the survey time series, the relative contribution to total survey biomass has shifted among strata from west to east (i.e. from 5Z5-5Z8 to 5Z1-5Z4; Figure 5). From the late 1980s to mid-1990s, 32-36% of total survey biomass occurred in stratum 5Z8 alone, but over the past 15 years, the contribution from this stratum has dropped to 7%. With the exception of stratum 5Z5, which contributed to 25% of total survey biomass in the late 1990s-early 2000s, all of the western strata combined (5Z5-5Z8) now contribute less than 25% of total survey biomass (2007-2011). Over the past decade, 29% of total survey biomass has come from stratum 5Z2, and recently, over half of total biomass has occurred in strata 5Z1 and 5Z2 combined.

There were approximately 150 individual fish codes recorded over the survey time series (1987-2011) (Table 7). The most frequently captured fish (> 60% of sets) were longhorn sculpin, winter skate, haddock, cod, little skate and sea raven, while those contributing most to the weight caught (> 40,000 kg) were haddock, spiny dogfish, cod, winter skate and longhorn sculpin.

There were 90 separate invertebrate codes used for the survey time series (Table 8). A broader sampling strategy implemented in 2007 has likely increased the experience of survey personnel in the identification of invertebrates. The most frequently captured were sea scallops, lobster, shortfin squid, sea stars, sponges and hermit crabs. Sea scallops, shortfin squid, lobster, sponges, sea stars and sand dollars contributed most to the weight of the invertebrate catch. Since 2007, the number of species codes used (fish and invertebrates combined) has generally been above the long term average for all survey strata (5Z1-5Z8) and for the strata used in TRAC assessments (5Z1-5Z4) (Figure 6). The contribution to total biomass from weighing catches of invertebrate species in addition to lobster and short-fin squid from 2007-2011 (i.e. sea scallop, sea stars, sea urchins, sponges, crabs) has represented on average an additional 10% for Strata 5Z5-5Z8 but less than 1% for strata 5Z1-5Z4. For all strata combined, the contribution of additional invertebrate species to total biomass from 2007-2011 was 4%.

Age information was available for cod and haddock for the entire survey time series (Table 9). Not all of the otoliths were aged each year for these species, especially when large numbers of fish were sampled (i.e. in 2011 only 599 of 1494 haddock otoliths collected were aged). The percentage of samples aged ranged from 44-99% for cod and 40-99% for haddock over the time series. The average ages for cod and haddock in the sample collections were 3-5 and 3-6, respectively. While pollock otoliths were collected in most years (excluding 1992), age determinations were completed for only the1989-1991 and 1994 survey sample collections. Currently, only pollock otoliths collected from the DFO summer RV survey are aged and used in calculations of indices of abundance for the analytical assessment. For yellowtail flounder, scale age information is available from 2004 to present with the percentage of samples aged ranging from 60-95% and average ages of 3-4.

DEPTH, BOTTOM TEMPERATURE AND SALINITY

The minimum and maximum tow depth (m) was recorded for each set as part of the standard survey protocol. The mean value for minimum and maximum tow depth grouped by stratum for all years combined fell within the general guidelines for stratum depth ranges (Table 10). Occasionally, maximum tow depths would exceed the upper bound for the stratum depth range for some strata (i.e. 5Z1, 5Z2, 5Z4, 5Z5 and 5Z8), however, because strata were also defined by geographic criteria rather than strictly by depth this was not considered to be problematic.

Hydrographic data was collected from a total of 1568 stations during the 1987-2011 time series (69% of all fishing sets; Table 11). Starting in 1999, the number of hydrographic stations was reduced to about 42% of all fishing stations. This approach was taken to save time since the AZMP did not require the full set of stations to characterize the hydrographic conditions on Georges Bank which tends to be vertically well mixed on top of the bank at this time of year. In 2006, the second year of the comparative fishing experiment, most of the hydrographic data was collected by the *Teleost*. This data was also included in the summaries of bottom temperature and salinity that follow.

Plots of mean bottom temperature by year indicate that there were consistent patterns among those strata located on top of the bank (i.e. 5Z2, 5Z3, 5Z4, 5Z6) (Figure 7) with annual mean temperatures falling both above and below the long term mean without any apparent trend. These shallower (< 93 m) strata were characterized cooler water temperatures (long term mean = 5.0 °C) compared to the deeper strata (93-183 m) along the southern flank (5Z8), northern edge (5Z1) and Great South Channel (5Z5). Stratum 5Z8 had the warmest long term mean bottom temperature (10.0 °C), followed by 5Z1 (7.0 °C) and 5Z5 (6.0 °C), all of which are influenced by intrusion of warmer slope waters originating from the

Gulf Stream (Mountain *et al.* 1989). Note that annual mean bottom temperatures were missing in some years due to lack of survey coverage for some of the western strata (5Z5-5Z8; Table 11, grey shading).

Similar to bottom temperature, plots of mean salinity (ppt) by year indicate a consistency in trends among strata located on top of the bank (5Z2, 5Z3, 5Z4, 5Z7) with salinities fluctuating around a long term mean of ~ 33 ppt (Figure 8). Some deeper strata were characterized by slightly higher average salinities (i.e. 5Z1: 34 ppt, 5Z8: 35 ppt) reflecting the influence of warmer, more saline waters originating from the Gulf Stream. For all strata, there was no apparent trend of increasing or decreasing salinity over the time series. Mean bottom depth, temperature and salinity data is summarized by year for each stratum in Appendix 1.

SPATIAL DISTRIBUTION, TOTAL BIOMASS AND ABUNDANCE AT SIZE FOR SELECTED SPECIES

Plots of spatial distribution (strata 5Z1-5Z8), total biomass (strata 5Z1-5Z4) and abundance at size (strata 5Z1-5Z4) are presented for selected fish and invertebrate species, generally those which occurred in more than 10% of all sets from 1987-2011. Exceptions to this rule were Atlantic halibut, redfish, cusk, Atlantic wolffish and smooth skate which were included since they occasionally occur as bycatch in mobile gear fisheries and may be of interest to fisheries managers. The selected species have been grouped into general categories (i.e. Commercial Groundfish, Flatfish, Other Groundfish, SARA/COSEWIC Species, Small Pelagics, Cartilagenous Fish and Invertebrates) and are discussed below.

Commercial Groundfish

Since the mid-1990s, **Atlantic cod** catches have occurred predominantly in Canadian waters on the northeastern part of the bank (Figure 9). Good catches also occurred in USA waters on western Georges Bank during the earlier years of the survey time series but this is not the case at present. The biomass index has fluctuated widely without trend throughout the time series and in 2011 was among the lowest levels observed (Figure 10). In 2010, abundance at length was above the median (50th percentile) for cod in the 55-85 cm range but below the median for fish < 55 cm (Figure 11). Cod abundance was below the median for most lengths in 2011, except at the 13, 31 and 70-76 cm groupings. Annual mean condition (Fulton's K) has declined over the time series, reaching the lowest value in 2011 (Figure 12). Cod condition has remained below the long term average since 2003.

Most of the maturity stage data for male and female cod was from fish sampled in 5Z1 (12%) and 5Z2 (65%). In stratum 5Z1, 68% of sampled fish were either

spent (stages 6-7) or recovering from spawning (stage 8), compared to 44% for 5Z2, where more fish were in the process of ripening and/or spawning (i.e. stages 2-5: 37-49% in 5Z2 *vs* 12-13% in 5Z1) (Figure 13). In the remaining strata (5Z3-5Z8), over 50% of the cod sampled had already spawned (stages 6-8) while about 22% (on average) were ripening and/or spawning (stages 2-5). During the months that these surveys were conducted (February-March), it appears that a slightly higher percentage of females had spawned and were recovering (stages 7-8) compared to males, for which a higher percentage were actually spawning or close to spawning (stages 4-6). While the size at maturity for male cod appears to be slightly smaller than females, there has been a temporal shift in the size at 50% mature for both sexes such that fish are currently maturing at smaller sizes in the recent period (2007-2011) compared to the early part of the time series (1987-1991) (Figure 14).

The distribution of **haddock** catches has been more widespread on northeastern Georges Bank over the past decade compared to the late 1980s and the 1990s, with good catches in Canadian waters in 5Z2 and in USA waters in 5Z3 and 5Z4 (Figure 15). The biomass index has shown a strong increase since 1997, with peaks in 2002 and 2008 (Figure 16). Although the index declined in 2011, it is still high compared to the pre-2000 period. Abundance indices for larger haddock in the 44-61 cm size categories have been above the median for the past two years (Figure 17). Notable in 2011 was the very high abundance of haddock in the 14-22 cm range, with record high abundance of fish in the 16.5 cm category (2010 year class). Haddock condition declined over the survey time series and reached the lowest observed level in 2011 (Figure 18). Since 2004, condition has been below the long term mean with the exception of 2009, when it was slightly above average.

Haddock maturity stage data was collected largely from fish sampled in 5Z2 (63%) and 5Z1 (19%); the remaining strata contributed fewer observations (18%). Across strata, there was a higher percentage of males which had spawned and were recovering (stages 6-8) compared to females, which had a higher percentage of ripening and spawning stages (stages 3-5) (Figure 19). Immature fish of both sexes (stage 1) were common across strata (20-60% of staged fish), with the exception of 5Z2 where pre-spawning and spent fish were more prevalent. The size at 50% maturity was slightly lower for males compared to females (Figure 20). Both sexes showed a decreasing trend in size at 50% maturity from the late 1980s to the mid 2000s, followed by an increase again in the recent period (2007-2011), but not to the level seen in the late 1980s.

Pollock catches have occurred in Canadian waters on the northeastern part of the bank throughout the survey time series (Figure 21). While sampling in stratum 5Z5 on western Georges Bank has been lower in recent years (2005-2011) compared to earlier on (1987-1992), pollock catches appear to have declined from this region. Considering that pollock are a schooling, semi-pelagic species, trends in total biomass from the Georges Bank survey tend to be quite

variable, but indicate a period of high abundance during the 1980s, low abundance in the 1990s, followed by an increase in the 2000s (Figure 22). In 2011, the survey biomass showed a dramatic increase from 2010. This increase is also reflected in the length-stratified abundance indices in 2011 which were well above the median for several size categories (i.e. 40-76 cm) (Figure 23). Fulton's condition factor, while variable, has declined over time reaching the lowest value in 2011 (Figure 24). Pollock condition has generally been below the long term mean for most years since 1999, with the exception of 2007. Maturity stage data was collected primarily from fish sampled in strata 5Z1 (32%) and 5Z2 (52%). For both sexes, 50-80% of the fish sampled in these strata had already completed spawning (maturity stages 6-8) by the time of the survey, while 18-33% were immature (Figure 25). Stratum 5Z1 was characterized by a higher percentage of fish that had already spawned compared to stratum 5Z2.

Since the early 1990s, **yellowtail flounder** catches have occurred predominantly on the northeastern part of Georges Bank, both in Canadian and USA waters (Stratum 5Z2 and 5Z4, respectively) (Figure 26). Noteworthy in 2008 and 2009 were the very high catches which occurred in deeper waters along the northeastern edge of stratum 5Z1, an area where they had not been observed previously. Total biomass increased between 1998 and 2001, declined to a low level in 2006, then increased dramatically in 2008 and 2009 with the high catches in stratum 5Z1 (Figure 27). Since 2009, total biomass has fallen off sharply and in 2011 dropped to a level not seen since the early 1990s. Abundance at length in 2010 was above the time series median for 32-34 cm and 37-45 cm fish but below the median for sizes < 32 cm (Figure 28). In 2011, abundance was below the median for most size categories with the exception of 39-41 cm fish. Yellowtail condition was below the long term mean since 2003 and reached the lowest value for both sexes in 2011 (Figure 29). The majority of yellowtail maturity observations were from strata 5Z2 (52%) and 5Z4 (24%). Most of the males examined were either ripening (stage 3) or ripe (stage 4), while females were predominantly ripening (stage 3) (Figure 30). Considering that peak spawning for yellowtail flounder on Georges Bank occurs from May to June (O'Brien et *al.* 1993), it is not unexpected that a large portion of mature fish would be in the ripening stages. Both strata exhibited similar patterns in maturity stages for males and females.

Flatfish

American plaice was captured at low levels throughout the survey area, although there were some higher catches on the northeastern part of the bank in 5Z2 during the1990s and early 2000s (Figure 31). Total biomass has fluctuated over the time series and reached peak levels during the 1990s and early 2000s before declining to near the lowest level in the time series in 2011 (Figure 32). Abundance of plaice in 2010 was above the median value for several length categories ranging from 7-8 cm and 22-33 cm, but below the median for larger

fish (> 34 cm) (Figure 33). Abundance in 2011 was near or above the median for lengths up to 32 cm, but below the median for most fish > 32 cm.

Winter flounder were generally captured in more shoal areas on the bank (i.e. 5Z6) during the early part of the time series when sampling intensity was higher in the western strata (Figure 34). The area of highest catches shifted to eastern Georges Bank (mainly 5Z2) during the 1990s to mid-2000s. While total biomass has shown strong fluctuations over the time series, current levels are much lower than they were prior to 2004 (Figure 35). Abundance at size for 2010 and 2011 was near the long term median distribution for fish ranging from 32-40 cm, but was below the median for smaller (<32 cm) and larger (> 40 cm) size categories (Figure 36).

Brill/windowpane flounder catches were widely distributed in the shallower strata located on top of the bank (5Z2-5Z4, 5Z6-5Z7), but were seldom caught in the deeper strata along the edge (5Z1, 5Z8, 5Z5) (Figure 37). Estimates of total biomass were variable but have been lower since 2002 and among the lowest in the time series in 2011 (Figure 38). Abundance at size was near the long term median in 2010 for fish in the 20-40 cm size range but below the median for these size groups in 2011 (Figure 39). The abundance of fish < 19 cm has exceeded the median for some length categories in the past 2 years indicating that there may be some new recruitment for this species.

The distribution of **four-spot flounder** was associated with deeper, warmer waters along the edge of the bank (Figure 40). Most large catches occurred in stratum 5Z8 and occasionally in 5Z1 but were uncommon in strata located on top of the bank where water temperatures tend to be lower. Estimates of total biomass were highly variable and without trend (Figure 41). Over the past two years, abundance exceeded the long term median for fish > 24 cm, but was low for fish < 24 cm (Figure 42).

Atlantic halibut were primarily captured along the northern edge of the bank in stratum 5Z2 but catches were very low (Figure 43). The biomass index was highly variable with generally lower estimates between 1998 and 2006 (Figure 44). Too few Atlantic halibut were captured for comparisons of abundance at size with the long term median.

Other Groundfish

Longhorn sculpin catches occurred mainly in Canadian waters on the northeastern part of the bank in 5Z2, especially during the 1990s (Figure 45). Good catches also occurred in USA waters on western Georges Bank during the earlier years of the survey time series. Peaks in total biomass occurred in 1995 and 2000 but since 2000 there has been a strong declining trend, with the 2011 estimate being at the lowest level in the time series (Figure 46). Abundance at

length in 2010 and 2011 was well below the long term median for all size categories (Figure 47).

Sea raven catches also occurred mainly on top of the bank, especially in strata 5Z2, 5Z3 and recently 5Z4 (Figure 48). Total biomass has fluctuated between 1300 t - 2500 t, with no real trend over the time series (Figure 49). Abundance at size in 2010 and 2011 was bimodal and was either close to or above the long term median for fish in the 10-13 cm and 32-53 cm size categories (Figure 50).

While the overall spatial distribution for **ocean pout** has not changed over the survey time series, catches have shown a substantial decline since the late 1990s (Figure 51). Noteworthy was that most catches from 1987-1992 were in 5Z6 and 5Z7, whereas in 1993-1998 they were caught mainly in 5Z2, a pattern that has persisted in recent years. Biomass estimates for ocean pout show a strong decline from the peak of 6347 t in 1989 to of 87 t in 2011, the second lowest level in the survey time series (Figure 52). Abundance at size in 2010 and 2011 indicates that there are currently low numbers of fish for lengths ranging from 55-83 cm compared to the long term median (Figure 53).

Catches of **monkfish** were low and occurred intermittently throughout the survey area (Figure 54). During the early part of the time series, most catches occurred in the western strata. Total biomass, although highly variable, followed a declining trend from 1996 to 2006, falling sharply to the lowest level in the time series in 2009, with a modest increase in 2011 (Figure 55). Too few monkfish were captured for comparisons of abundance at size with the long term median.

Redfish were caught only in stratum 5Z5 throughout the survey time series (Figure 56). Total biomass was highly variable between years where catches were large or nonexistent (Figure 57). Too few redfish were captured for comparisons of abundance at size with the long term median.

Red hake were caught in deeper waters along the edge of the bank in strata 5Z1, 5Z3, 5Z5 and 5Z8, especially during the earlier years of the time series (1987-1992) (Figure 58). While their overall spatial distribution essentially remains unchanged, current catches in these strata are now much lower. Total biomass fluctuated well under 1000 t for the majority of the time series except in 1987 and 2008 when very large catches occurred (Figure 59). In 2010 and 2011, total abundance at size exceeded the long term median for most length categories (Figure 60).

White hake were also captured in deeper waters along the edge of the bank in strata 5Z1, 5Z3, 5Z5 and 5Z8), especially during the earlier years of the time series (1987-1992) (Figure 61). Catches have declined in all strata over time. Total biomass has fluctuated widely over the time series without trend but appears to be at a lower level since 2005 (Figure 62). Too few white hake were captured for comparisons of abundance at size with the long term median.

Silver hake were caught predominantly in deeper waters along the edge of the bank in strata 5Z1, 5Z3, 5Z5, 5Z7 and 5Z8 (Figure 63). The most significant change over the time series was the decline in catches from 5Z8. This may in part be due to a decrease in sampling effort in 5Z8 since 1992 rather than absence of fish. Silver hake biomass has fluctuated without trend but appears to have been higher during the late 1990s than it is at present (Figure 64). In 2011, there was an increase in the abundance of large-sized individuals (17-25 cm) compared to 2010 when more small fish (11-16 cm) were present, indicating possible year class progression (Figure 65). In both years, abundance was well above the long term median for most length categories.

Very few **cusk** were captured in the Georges Bank survey. Catch locations were generally along the northern and northeastern edges of the bank in 5Z2, 5Z3 and 5Z5 (Figure 66). Total biomass was variable, but indicates that the population has been at a lower level since the early 1990s (Figure 67). Too few cusk have been captured for comparisons of abundance at size with the long term median. Currently, cusk has "no status" under SARA but is considered to be "threatened" according to the assessment of COSEWIC.

Atlantic wolffish catches have consistently occurred on northeastern Georges Bank in Canadian waters throughout the time series, although catches are currently much lower now than in the past (Figure 68). There were also catches of wolfish off Cape Cod and the Nantucket Shoals in stratum 5Z6 during the early years of the survey program (1987-1992). Total biomass appears to have been highest in 1987, then fluctuated between about 200-500 t before declining to < 40 t in 2006 and has remained at low levels ever since (Figure 69). Too few wolffish have been captured for comparisons of abundance at size with the long term median. Atlantic wolffish was given the designation of "special concern" under COSEWIC and SARA.

Small Pelagics

Herring were caught in several strata on top of the bank, with the largest catches in USA waters in strata 5Z6, 5Z7 and 5Z4 (Figure 70). Currently, most catches occur in stratum 5Z6. Total biomass reached highest levels in 1993, 1999 and 2001 but has been low since 2002 with only a modest increase in recent years (Figure 71). Abundance for the past two years has exceeded the long term median for most size categories and clearly indicates the progression of a strong year class from 2010 (11-15 cm) to 2011 (18-24 cm) (Figure 72).

Mackerel catches have been sporadic and mainly in USA waters in strata 5Z6 and 5Z7 (Figure 73). Since 1999, there have also been catches in strata 5Z2, 5Z3 and 5Z4. Similar to herring, mackerel biomass peaked in 2001 (Figure 74). However, other than a few years in the early 2000s, biomass has been low

throughout the time series. In 2010, abundance at size was bimodal with peaks in the 25-28 cm and 31-40 cm length categories while in 2011, smaller fish (25-28 cm) were most abundant (Figure 75). Abundance in 2010 and 2011 exceeded the long term median.

Cartilaginous Fish

During the early years of the survey program (1987-1992), **spiny dogfish** were caught all along the southern flank extending from the Nantucket Shoals to the Northeast Peak (Strata 5Z1, 5Z2, 5Z4, 5Z7 and 5Z8 (Figure 76). Catches declined through the1990s and 2000s and spatial distribution contracted to the northeastern part of the bank. The decline in distribution and catches during the time series corresponded to the sharp decline in biomass after 1995, which has remained low ever since (Figure 77). There were no catches of dogfish during the 2011 survey. Median (1987-2009) size composition was represented by fish in the 52 cm to 91 cm range, peaking at about 73 cm (Figure 78).

Winter skate catches were widely distributed throughout the survey area, both along the edge and on top of the bank (Figure 79). Recently, most of the larger catches have occurred near the edge of the bank in strata 5Z1-5Z4. Total biomass had a pronounced decline from 1987 to 1992 and has been variable but slowly declining since then (Figure 80). In the past two years, abundance has exceeded the long term median for smaller sizes (15-37 cm) but was generally well below the median for larger size categories (> 37 cm) (Figure 81).

Little skate were also widely distributed on top of the bank with the highest catches occurring in the western strata (5Z4, 5Z6, 5Z7) since 2005 (Figure 82). Biomass has been highly variable and was at its lowest level in the time series in 2011 (Figure 83). Abundance at size in 2010 and 2011 showed strong bimodality unlike the long term median (Figure 83). Little skate abundance at sizes < 37 cm was well above the median but for size categories >37 cm was less than half of the median (Figure 84). A progressive increase in size composition was apparent from 2010 to 2011. It has long been recognized that the identification of little and winter skates can be difficult at sizes below 35 cm, thus there may be some unquantifiable error in the abundance at size for smaller individuals.

Catches of **barndoor skate** were low and occurred primarily along the southern flank from the Nantucket Shoals to the Northeast Peak (Figure 85). Since the mid-2000s, most catches have been in strata 5Z2 and 5Z4. The biomass index has been highly variable with peaks in 1999 and 2003 (Figure 86). Total biomass decreased in 2006 to a low in 2008 but appears to be increasing again. For the past two years, total stratified abundance has been well above the median for barndoor skates in the 22-76 cm size categories (Figure 87).

Thorny skate have been consistently captured in stratum 5Z2, although some catches also occurred in 5Z5 and 5Z6 during the early years of the time series (1987-1992) (Figure 88). Total biomass declined from a peak in 1991 (642 t) to the lowest level in the time series in 2009 (12 t), with a modest increase since then (i.e. 72 t in 2010 and 2011) (Figure 89). Over the past two years, the abundance of small thorny skates (5-19 cm size groupings) has exceeded the long term median, while larger individuals (> 19 cm) were absent (Figure 90).

Very few **smooth skate** were captured during the Georges Bank survey, with some small catches recorded in 5Z2 and 5Z5 over the past decade (Figure 91). Total biomass was highly variable and fluctuated between 15-40 t (Figure 92). In 2011, biomass was estimated at 14 t. Too few smooth skate were captured for comparisons of abundance at size with the long term median.

Invertebrates

Catches of **American lobster** were primarily in strata 5Z1, 5Z2 and 5Z3, with both the distribution and magnitude of catches increasing over the past 7 years (2005-2011) (Figure 93). Total biomass, while variable, has increased over the 25 year time series and reached an all-time high of 1863 t in 2011 (Figure 94). The abundance of lobsters in 2011 with carapace lengths of 42 mm, 67-72 mm and 92-122 mm was well above the median for 2006-2009 (Figure 95). Abundance at length also exceeded the median in 2010 but with approximately half the number of individuals compared to 2011.

Sea scallop catches have been recorded since 2000 and were distributed mainly on eastern Georges Bank (strata 5Z2-5Z4) during the early 2000s, with some good catches on the western part of the bank (5Z6) in recent years (Figure 96). Total biomass peaked in 2002, declined to low levels from 2006-2008 then increased to the second highest level in the time series in 2010, before dropping off slightly in 2011 (Figure 97). Abundance at size in 2010 and 2011 was above the 2006-2009 median for scallops in the 80-123 mm shell height range, although both smaller (< 80 mm) and larger (> 123 mm) scallops were present in 2010 (Figure 98).

Shortfin squid were caught mainly in deeper, warmer waters along the shelf edge in stratum 5Z8 with some small catches in stratum 5Z1 (Figure 99). Total biomass has been variable without trend (Figure 100). Abundance at length shifted to smaller size-classes between 2010 and 2011 (i.e. from 6-26 cm to 3-14 cm mantle length; Figure 101). Abundance estimates in 2010 and 2011 exceeded the median for 2006-2009.

CONCLUSIONS

Data collected from the Georges Bank bottom trawl survey are useful for monitoring temporal and spatial trends in the distribution, abundance and biomass for several fish and invertebrate species and for monitoring temporal and spatial variability in hydrographic conditions across the bank. In addition, the data provide a primary source of information that can further our understanding of of long term changes in the species composition and biodiversity of the Georges Bank ecosystem. Estimated total survey biomass, although somewhat cyclic, has generally declined over the time series and is currently at the lowest observed level (Figure 102). Coupled with this decline has been a geographic shift in total biomass after 2001 from western strata (5Z5-5Z8) to eastern strata (5Z1-5Z4). Part of this shift may be related to the decline in biomass of spiny dogfish in the west and the increase in biomass of haddock in the east.

Recently, DFO Resource Management has requested Summer RV survey information on Scotian Shelf stocks through the "Science Special Response Process" to compare current biomass levels with those from short (5-yr), medium (15-yr) and long term (full time series) periods (DFO 2011). This type of information is used by Fisheries Managers to evaluate the effectiveness of management measures for groundfish stocks or species that may not be assessed on a routine basis or which may be moving towards multi-year assessments.

For the Georges Bank survey, comparisons of total biomass in 2011 with mean biomass for short (2005-2009), medium (1995-2009) and long term (1987-2009) periods reveal some interesting trends for the 30 species examined in this document (Table 12). Current (2011) biomass estimates were clearly below the short, medium and long term averages for 17 of 30 species examined (57%), while only 7 of 30 (23%) had 2011 biomass estimates which exceeded the short, medium and long term averages. For the remaining 6 species, average biomass for short, medium and long periods were less consistent. Noteworthy is that lobster and sea scallop have shown a strong increase in biomass in recent years, while several fish species have shown declines. Some of these species like flatfish (American plaice, winter flounder, brill/windowpane flounder), skates (winter skate, little skate), spiny dogfish and other groundfish (longhorn sculpin, ocean pout, monkfish) are captured incidentally as bycatch in mobile and fixed gear fisheries for groundfish and in the offshore scallop fishery (Gavaris et.*al.* 2010). While it is possible that some of the decline in biomass of these species may be due to incidental mortality in these fisheries there may be other factors as well. In any case, the only source of long-term monitoring for these species would be from Georges Bank survey data.

The strong decline in condition factor for cod, haddock, pollock and yellowtail flounder since the mid-2000s is puzzling and could be influenced by several

factors including climate change, variability on oceanographic conditions over long time scales (i.e. North Atlantic Oscillation) as well as various anthropogenic affects.

The survey data are available on the Maritimes Regional Ecosystem Survey database for more detailed analyses.

ACKNOWLEDGEMENTS

We thank D. Clark, L. Van Eeckhaute, J. Emberley, S. Gavaris, P. Comeau and Y. Wang for providing helpful comments on earlier drafts of the manuscript.

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Table 1. Set allocation, depth range (m), trawlable units and area (square nautical miles) for each stratum from the Georges Bank survey. Stratum 5Z9 was introduced in 2010 and has not been included in subsequent analyses. (A trawlable unit =1.75 nautical miles (standardized tow length) x 0.00675 nautical miles (wingspread) = 0.01181 square nautical miles).

Strata	Set allocation			Depth range (m)	Trawlable units	Square nautical miles
	Primary	Secondary	Total			
5Z1	6	4	10	93-183	67369	795
5Z2	20	15	35	<93	106096	1252
5Z3	10	5	15	0-183	194482	2295
5Z4	10	5	15	<93	260919	3079
5Z5	5		5	93-183	197956	2336
5Z6	8	4	12	<93	138807	1638
5Z7	5		5	<93	271088	3199
5Z8	3		3	93-183	170669	2014
5Z9 (2010-present)	3		3	>183	61014	720
Total	70	33	103		1468400	17328

Table 2. Year, mission number, sets completed and start and end date for DFO surveys conducted on Georges Bank, 1987-2011 (NED: *Alfred Needler*; TEM: *Wilfred Templeman*; TEL: *Teleost*).

Year	Mission number	No.of Sets	Start Date	End Date
1987	NED1987077	68	10-Mar	18-Mar
1988	NED1988097	132	01-Mar	15-Mar
1989	NED1989116	116	23-Feb	06-Mar
1990	NED1990133	123	21-Feb	06-Mar
1991	NED1991148	132	13-Feb	27-Feb
1992	NED1992165	91	26-Feb	11-Mar
1993	TEM1993134	65	09-Mar	18-Mar
1994	NED1994200	45	16-Feb	24-Feb
1995	NED1995216	85	15-Feb	23-Feb
1996	NED1996237	86	20-Feb	29-Feb
1997	NED1997254	90	25-Feb	05-Mar
1998	NED1998773	96	17-Feb	26-Feb
1999	NED1999871	82	16-Feb	24-Feb
2000	NED2000965	100	16-Feb	24-Feb
2001	NED2001003	76	14-Feb	23-Feb
2002	NED2002002	89	19-Feb	28-Feb
2003	NED2003002	98	17-Feb	27-Feb
2004	TEM2004004	85	06-Feb	15-Feb
2005	NED2005001, TEL2005545	131	19-Feb	06-Mar
2006	NED2006001, TEL2006614	92	20-Feb	28-Feb
2007	TEM2007685	88	20-Feb	02-Mar
2008	TEM2008775	69	04-Mar	20-Mar
2009	NED2009841	68	13-Feb	26-Mar
2010	NED2010001	63	27-Feb	08-Mar
2011	NED2011002	97	22-Feb	14-Mar

Table 3. Ageing material collected by species during the Georges Bank survey from 1987-2011 for strata 5Z1-5Z8. Yellowtail flounder were sampled for otoliths from 1987-1991 and 1996-2003 and for scales from 2004 onward.

	Ageing material collected by species						
Year	Cod	Haddock	Wh. Hake	Cusk	Pollock	Halibut	Yellowtail
1987	333	294			118		221
1988	971	961			269		311
1989	1068	728			218		246
1990	1372	1070			132		526
1991	1223	1049			199		477
1992	923	657					
1993	703	606			21		
1994	464	466			44		
1995	456	700			45		
1996	814	991			71		607
1997	627	823			58		847
1998	580	1026			71		512
1999	544	889			18		783
2000	572	1097			85		1140
2001	543	1076			42		886
2002	738	1527			159		667
2003	528	1177			193		682
2004	422	1357			98		562
2005	749	1292			135		509
2006	691	1782			99		514
2007	807	1215	5	2	55		709
2008	542	1042		1	56	1	508
2009	285	557			11	2	247
2010	449	799	14		13		385
2011	612	1494	19	1	113	7	359
Total	17016	24675	38	4	2323	10	11698

Table 4. Maturity stages (based on Kesteven 1960) used to classify maturity for selected groundfish species sampled from the Georges Bank survey, 1987-2011.

Stage	Female	Male
Stage 1 (Immature)	Ovaries small and firm; pale pink or reddish; and somewhat transparent.	Testes slender; appear as a clear, crimped, and slender string.
Stage 2 (Ripening 1)	Ovaries slightly larger than in 1 but still small and firm; contains microscopic, yellow or reddish yellow, opaque eggs; blood capillaries showing.	Testes grow gradually in size; pinkish or flesh coloured; blood capillaries showing.
Stage 3 (Ripening 2)	Ovaries occupy about half of ventral cavity; reddish and numerous blood vessels; opaque eggs are now visible to naked eye and give the ovaries a grandular appearance.	Testes occupy about half ventral cavity; begin to turn white, with fine, rather conspicuous, blood vessels; no milt runs when pressure is applied.
Stage 4 (Ripe)	A few clear eggs at the earliest stage, progressing to mainly clear eggs, but eggs do not extrude freely with slight pressure. Spawning has not started.	Testes distinctly wavy, white, and quite distended; large lobes; a small amount of milt may be forced out with pressure.
Stage 5 (Spawning)	As Stage 4, but eggs running freely on slight pressure.	Testes very white and fully extended; milt runs freely at the slightest pressure.
Stage 6 (Spent)	Ovaries soft; flabby, and bloody; practically no eggs remain; purple in colour.	Testes shrunken and reddish; vas deferens prominent against irregular surfaces of testes; some blood left in organ.
Stage 7 (Recovering)	Membrane purplish and ovaries fairly baggy; no eggs visible.	Testes resume pale pink colour; traces of blood in organ; vas deferens wrinkled and string-like.
Stage 8 (Resting)	Looks very much like Stage 1, but is found in large fish; ovary larger than in 1, also membrane thicker and not as transparent.	Testes larger than in 1; surface regular; some greyish pink in colour.

Table 5. Groundfish maturity data by stage (1-8) and species from Georges Bank surveys conducted from 1987 to 2011 for strata 5Z1-5Z8.

Species	Years collected	Maturity stage 1	2	3	4	5	6	7	8	Grand Total
Cod	1987-2011	2079	475	1382	2246	2296	2329	2032	4136	16975
Haddock	1987-2011	4385	1612	4697	2564	1205	5623	2655	1871	24612
White Hake	2010, 2011	17		3	1		3	1	7	32
Silver Hake	1989, 1990	18	19	88	7		3	11	30	176
Cusk	2007, 2008, 2011		1	1	1				1	4
Pollock	1987-1991, 1993-2011	388	24	41	28	19	129	221	752	1582
Halibut	2008, 2009, 2011	6	2						3	11
Yellowtail	1987-1991, 1997, 1999, 2003	192	273	1369	556	108	46	15	69	2628
Total by stage		7065	2406	7581	5403	3628	8133	4935	6869	46020

Table 6. Number of sets sampled by stratum for the Georges Bank survey, 1987-2011. Grey shading indicates years and strata which were not sampled due to time constraints from inclement weather or mechanical problems. The total compliment of stations for strata 5Z1-5Z8 was 140 from 1988-1991 and 100 from 1992 to present. The average number and percentage of stations completed for the current set allocation (1992-2011) is also shown.

	Number of sets sampled by strata 5Z1	5Z2	5Z3	5Z4	5Z5	5Z6	5Z7	5Z8	Annual total
1987	9	7	7	11	9	5	12	8	68
1988	24	28	16	16	12	11	15	10	132
1989	18	25	12	15	12	9	16	9	116
1990	23	22	14	16	13	8	17	10	123
1991	23	25	13	17	12	14	18	10	132
1992	11	32	11	15	4	10	5	3	91
1993	10	36	11	6				2	65
1994	6	24	9	5				1	45
1995	9	32	11	12	5	10	4	2	85
1996	9	33	14	13	4	9	3	1	86
1997	9	32	11	15	5	11	4	3	90
1998	10	37	16	13	5	9	4	2	96
1999	8	31	10	15	3	8	4	3	82
2000	10	35	15	15	5	12	5	3	100
2001	9	33	9	13	3	3	3	3	76
2002	10	34	5	15	5	12	5	3	89
2003	11	37	15	13	4	11	4	3	98
2004	10	35	11	12	4	8	3	2	85
2005	14	48	25	20	4	12	5	3	131
2006	12	39	14	20		4	1	2	92
2007	10	35	11	15	1	11	5		88
2008	8	26	11	12	2	6	2	2	69
2009	6	19	12	13	5	9	4		68
2010	9	23	15	10	3			3	63
2011	10	35	14	15	5	10	5	3	97
Stratum Total	288	763	312	342	125	202	144	91	2267
Avg. # (1992-2011)	9.6	32.8	12.5	13.4	3.9	9.1	3.9	2.4	85
Avg. % (1992-2011)	95.5	93.7	83.3	89.0	78.8	76.0	77.6	81.5	84.8

Table 7. Summary of fish catches (number and frequency of sets occupied, total weight (kg) and total number) by species from the Georges Bank survey for all strata (5Z1-5Z8) and years (1987-2011) combined. The number of individual lengths and weights recorded is also indicated. (ns = non-specified).

Species code	Common name	Scientific name	Number of sets occupied	Frequency (%) of sets occupied	Total weight (kg)	Total number	No. of individual lengths	No. of individual weights
10	Cod (Atlantic)	*Gadus morhua*	1549	68.33	100250	33279	28140	16963
11	Haddock	*Melanogrammus aeglefinus*	1572	69.34	281556	339810	125864	24975
12	White Hake	*Urophycis tenuis*	312	13.76	993	2304	2304	96
13	Squirrel or Red Hake	*Urophycis chuss*	442	19.5	3284	17381	11016	395
14	Silver Hake	*Merluccius bilinearis*	656	28.94	8018	121278	40955	972
15	Cusk	*Brosme brosme*	43	1.9	170	66	66	10
16	Pollock	*Pollachius virens*	428	18.88	30043	15335	6457	2325
20	Redfish	*Sebastes marinus*	3	0.13	6	42	42	17
23	Redfish unseparated	*Sebastes* sp.	101	4.46	1575	4428	2871	195
25	Tile Fish	*Lopholatilus chamaeleonticeps*	1	0.04	1	1	1	0
30	Halibut (Atlantic)	*Hippoglossus hippoglossus*	61	2.69	296	76	76	16
31	Turbot/Greenland Halibut	*Reinhardtius hippoglossoides*	2	0.09	1	2	2	0
40	American Plaice	*Hippoglossoides platessoides*	1015	44.77	3013	8625	8625	901
41	Witch Flounder	*Glyptocephalus cynoglossus*	134	5.91	179	439	439	31
42	Yellowtail Flounder	*Limanda ferruginea*	1348	59.46	40641	100518	45948	11916
43	Winter Flounder	*Pseudopleuronectes americanus*	816	35.99	4398	5160	5078	411
44	Gulf Stream Flounder	*Citharichthys arctifrons*	171	7.54	14	889	888	49
50	Striped Atlantic Wolffish	*Anarhichas lupus*	138	6.09	1681	283	282	14
52	Northern Wolffish	*Anarhichas denticulatus*	1	0.04	2	1	1	1
60	Herring (Atlantic)	*Clupea harengus*	836	36.88	13044	161944	44011	1009
61	American Shad	*Alosa sapidissima*	146	6.44	286	932	934	47
62	Alewife	*Alosa pseudoharengus*	309	13.63	1097	10120	6751	277
63	Rainbow Smelt	*Osmerus mordax*	1	0.04	0	55	55	3
70	Mackerel (Atlantic)	*Scomber scombrus*	351	15.48	6727	46929	8733	395
102	Scup	*Stenotomus chrysops*	4	0.18	0	4	4	0
111	Spotted Hake	*Urophycis regia*	10	0.44	5	32	32	4
112	Longfin Hake	*Urophycis chesteri*	4	0.18	5	28	28	1
114	Fourbeard Rockling	*Enchelyopus cimbrius*	50	2.21	4	108	108	7
122	Cunner	*Tautogolabrus adspersus*	218	9.62	560	929	927	53
123	Blackbelly Rosefish	*Helicolenus dactylopterus*	31	1.37	1	63	63	9

Table 7. Continued

Species code	Common name	Scientific name	Number of sets occupied	Frequency (%) of sets occupied	Total weight (kg)	Total number	No. of individual lengths	No. of individual weights
141	Summer Flounder	*Paralichthys dentatus*	72	3.16	318	347	346	13
142	Fourspot Flounder	*Hippoglossina oblonga*	357	15.75	1337	7387	6268	243
143	Brill/Windowpane	*Scophthalmus aquosus*	1083	47.77	4496	18711	17563	1300
149	Longnose Greeneye	*Parasudis truculenta*	2	0.09	0	47	47	0
150	Lanternfish (NS)	Myctophidae	22	0.97	1	97	96	12
152	Lanternfish	*Diaphus dumerili*	1	0.04	0	1	1	1
156	Shortnose Greeneye	*Chlorophthalmus agassizi*	1	0.04	0	1	1	0
158	Muller's Pearlsides	*Maurolicus muelleri*	7	0.31	5	56	56	5
159	Boa Dragonfish	*Stomias boa*	1	0.04	0	1	1	0
160	Argentine (Atlantic)	*Argentina silus*	4	0.18	0	8	8	0
164	Menhaden (Atlantic)	*Brevoortia tyrannus*	1	0.04	2	1	1	0
165	Blueback Herring	*Alosa aestivalis*	8	0.35	23	448	173	0
200	Barndoor Skate	*Dipturus laevis*	198	8.73	555	562	562	158
201	Thorny Skate	*Amblyraja radiata*	328	14.47	1316	1057	1057	143
202	Smooth Skate	*Malacoraja senta*	90	3.97	89	201	201	33
203	Little Skate	*Leucoraja erinacea*	1483	65.42	22284	37214	32819	2366
204	Winter Skate	*Leucoraja ocellata*	1601	70.62	44953	37644	35710	3503
206	Brier Skate	*Raja eglanteria*	3	0.13	5	9	9	0
207	Round Skate	*Rajella fyllae*	8	0.35	4	25	4	0
215	Sand Shark	*Carcharias taurus*	1	0.04	8	1	1	0
216	Atlantic Torpedo	*Torpedo nobiliana*	1	0.04	5	2	2	0
220	Spiny Dogfish	*Squalus acanthias*	793	34.98	107541	113699	25068	578
230	Porbeagle/Mackerel Shark	*Lamna nasus*	1	0.04	19	1	1	0
240	Sea Lamprey	*Petromyzon marinus*	42	1.85	3	60	59	28
241	Northern Hagfish	*Myxine glutinosa*	16	0.71	1	19	19	7
300	Longhorn Sculpin	*Myoxocephalus octodecemspinosus*	1700	74.99	40241	196936	62128	2525
301	Shorthorn Sculpin	*Myoxocephalus scorpius*	10	0.44	1	311	186	21
303	Grubby or Little Sculpin	*Myoxocephalus aenaeus*	4	0.18	0	4	4	1
304	Mailed Sculpin	*Triglops murrayi*	195	8.6	31	6715	5213	194
306	Snowflake Hookear Sculpin	*Artediellus uncinatus*	26	1.15	0	289	294	0

Table 7. Continued

Species code	Common name	Scientific name	Number of sets occupied	Frequency (%) of sets occupied	Total weight (kg)	Total number	No. of individual lengths	No. of individual weights
307	Polar Sculpin	*Cottunculus microps*	3	0.13	0	9	9	5
309	Sculpin (ns)	*Triglops* sp.	3	0.13	0	175	175	13
313	Twohorn Sculpin	*Icelus bicornis*	1	0.04	0	2	2	2
314	Spatulate Sculpin	*Icelus spatula*	14	0.62	0	112	112	17
320	Sea Raven	*Hemitripterus americanus*	1383	61.01	6423	6802	6788	1106
323	Hookear Sculpin (ns)	*Artediellus* sp.	5	0.22	0	15	15	1
330	Northern/Common Searobin	*Prionotus carolinus*	14	0.62	286	1421	195	0
331	Armored Searobin	*Peristedion miniatum*	5	0.22	2	7	7	1
340	Alligatorfish	*Aspidophoroides monopterygius*	105	4.63	1	619	551	84
353	Bigeye	*Priacanthus arenatus*	1	0.04	0	1	1	1
400	Monkfish/Goosefish/Angler	*Lophius americanus*	244	10.76	711	406	404	24
431	Conger sp.	*Conger* sp.	1	0.04	0	1	1	0
500	Seasnail unidentified	*Liparis* sp.	11	0.49	0	14	14	0
501	Lumpfish	*Cyclopterus lumpus*	31	1.37	195	45	45	3
502	Atlantic Spiny Lumpsucker	*Eumicrotremus spinosus*	1	0.04	0	1	1	1
503	Atlantic Seasnail	*Liparis atlanticus*	6	0.26	0	10	10	1
504	Striped Seasnail	*Liparis liparis*	1	0.04	0	1	1	1
505	Gelatinous Seasnail	*Liparis fabricii*	13	0.57	0	17	17	7
508	Inquiline Seasnail	*Liparis inquilinus*	1	0.04	0	1	1	0
511	Blacksnout Seasnail	*Paraliparis copei*	1	0.04	0	1	1	0
512	Dusky Seasnail	*Liparis gibbus*	19	0.84	0	27	27	12
600	American Eel	*Anguilla rostrata*	3	0.13	3	7	7	0
602	Gray's Cutthroat Eel	*Synaphobranchus kaupi*	3	0.13	2	3	3	0
603	Wolf Eelpout	*Lycenchelys verrilli*	1	0.04	0	1	1	0
604	Snipe Eel	*Nemichthys scolopaceus*	3	0.13	0	5	5	0
607	Duckbill Oceanic Eel	*Nessorhamphus ingolfianus*	4	0.18	6	24	24	0
608	Conger Eel	*Conger oceanicus*	4	0.18	6	5	5	1
609	Snake Eel	*Ophichthus cruentifer*	4	0.18	2	39	39	0
610	Northern Sand Lance	*Ammodytes dubius*	118	5.21	74	6154	2232	168
617	Common Wolf Eel	*Lycenchelys paxillus*	2	0.09	0	6	6	0

Table 7. Continued

Species code	Common name	Scientific name	Number of sets occupied	Frequency (%) of sets occupied	Total weight (kg)	Total number	No. of individual lengths	No. of individual weights
621	Rock Gunnel (Eel)	*Pholis gunnellus*	2	0.09	0	2	1	0
622	Snake Blenny	*Lumpenus lumpretaeformis*	23	1.01	9	192	192	13
625	Radiated Shanny	*Ulvaria subbifurcata*	20	0.88	0	49	49	7
626	Fourline Snakeblenny	*Eumesogrammus praecisus*	4	0.18	0	12	12	9
630	Wrymouth	*Cryptacanthodes maculatus*	9	0.4	3	10	10	1
633	Banded Gunnel	*Pholis fasciata*	2	0.09	0	2	2	2
635	Dragonets	Callionymidae	1	0.04	0	2	2	2
639	Pricklebacks	Stichaeidae	3	0.13	0	8	8	0
640	Ocean Pout (Common)	*Macrozoarces americanus*	1072	47.29	6350	6840	6835	586
647	Shorttailed Eelpout (Vahl)	*Lycodes vahlii*	1	0.04	0	1	1	0
650	Fawn Cusk Eel	*Lepophidium profundorum*	26	1.15	8	179	179	6
652	Percoidei	Percoidei	4	0.18	0	10	10	0
657	Callionymus sp.	*Callionymus* sp.	2	0.09	0	3	3	0
660	Cusk Eels (ns)	Ophidioidei	7	0.31	10	124	124	0
701	Butterfish	*Peprilus triacanthus*	149	6.57	540	9935	3946	44
702	Northern Pipefish	*Syngnathus fuscus*	7	0.31	0	8	8	2
704	American John Dory	*Zenopsis ocellata*	9	0.4	20	61	61	5
712	White Barracudina	*Notolepis rissoi*	1	0.04	0	1	1	0
759	Pipefish unidentified	*Syngnathus* sp.	13	0.57	0	19	19	3
770	Atlantic Silverside	*Menidia menidia*	2	0.09	0	2	2	0
868	Seasnail	*Paraliparis calidus*	1	0.04	0	1	1	1
880	Hookear Sculpin (Atlantic)	*Artediellus atlanticus*	50	2.21	2	378	378	11
924	Sea Tadpole	*Careproctus ranula*	2	0.09	0	2	2	0
946	Blennies (ns)	*Lumpenus* sp.	3	0.13	7	159	159	9
1101	Boarfish	*Antigonia* sp.	1	0.04	0	1	1	1
1199	Purse Barndoor Skate	Purse barndoor skate	1	0.04	0	1		
1203	Purse Little Skate	Purse little skate	17	0.75	0	51		
1204	Purse Winter Skate	Purse winter skate	16	0.71	0	46		
1218	Sea Raven eggs	*Hemitripterus americanus* eggs	1	0.04	0	1		
1224	Skate unidentified, eggs	*Raja*, eggs	51	2.25	1	126		

Table 8. Summary of invertebrate catches (number and frequency of sets occupied, total weight (kg) and total number) by species from the Georges Bank survey for all strata (5Z1-5Z8) and years (1987-2011) combined. The number of individual lengths and weights recorded is also indicated. (ns = non-specified).

Species code	Common name	Scientific name	Number of sets occupied	Frequency (%) of sets occupied	Total weight (kg)	Total number	No. of individual lengths	No. of individual weights
1510	Whelk eggs (ns)	Buccinidae eggs	11	0.49	8	2		
1810	Tunicata	Tunicata	14	0.62	9	12		
1822	Dendrodoa sp.	*Dendrodoa* sp.	1	0.04	0	6		
1823	Sea Potato	*Boltenia* sp.	57	2.51	16	144		
1827	Sea Peach	*Halocynthia pyriformis*	1	0.04	0	0		
2211	Pandalus borealis	*Pandalus borealis*	33	1.46	18	5800		
2212	Pandalus montagui	*Pandalus montagui*	73	3.22	16	11575		
2221	Pasiphaea multidentata	*Pasiphaea multidentata*	3	0.13	1	372		
2312	Lebbeus polaris	*Lebbeus polaris*	2	0.09	0	10		
2316	Spirontocaris spinus	*Spirontocaris spinus*	1	0.04	0	4		
2319	Lebbeus groenlandicus	*Lebbeus groenlandicus*	4	0.18	0	13		
2320	Lebbeus sp.	*Lebbeus* sp.	1	0.04	0	5		
2333	Eualus gaimardii	*Eualus gaimardii*	1	0.04	0	1		
2415	Pontophilus norvegicus	*Pontophilus norvegicus*	2	0.09	0	4		
2416	Crangon sp.	*Crangon* sp.	20	0.88	0	725		
2417	Crangon septemspinosa	*Crangon septemspinosa*	9	0.4	0	301		
2509	Cancer Crab (ns)	Cancridae	3	0.13	1	96		
2510	Brachiuran Crabs	Brachyura s.	1	0.04	0	1	1	1
2511	Jonah Crab	*Cancer borealis*	76	3.35	20	156	117	112
2513	Atlantic Rock Crab	*Cancer irroratus*	153	6.75	68	1708	1629	1042
2520	Toad Crab unidentified	*Hyas* sp.	8	0.35	0	60		
2521	Hyas coarctatus	*Hyas coarctatus*	48	2.12	1	332	332	205
2523	Northern Stone Crab	*Lithodes maja*	5	0.22	1	3	2	2
2524	Cancer sp.	*Cancer* sp.	4	0.18	0	16		
2526	Snow Crab (Queen)	*Chionoecetes opilio*	2	0.09	0	1		
2527	Toad Crab	*Hyas araneus*	34	1.5	1	440	205	113
2532	Red Deepsea Crab	*Chaceon quinquedens*	8	0.35	8	32	24	22
2550	American Lobster	*Homarus americanus*	423	18.66	1778	1453	654	538
2559	Hermit Crabs	Paguridae	233	7.68	26	719		
2621	Thysanoessa raschii	*Thysanoessa raschii*	1	0.04	0	100		

Table 8. Continued

Species code	Common name	Scientific name	Number of sets occupied	Frequency (%) of sets occupied	Total weight (kg)	Total number	No. of individual lengths	No. of individual weights
2990	Barnacles	Cirripedia	16	0.71	3	47		
3100	Bristle Worms	Polychaeta	5	0.22	0	203		
3130	Nereis sp.	*Nereis* sp.	1	0.04	0	1		
3200	Sea Mouse	*Aphrodita hastata*	16	0.71	4	91		
3212	Aphrodita sp.	*Aphrodita* sp.	74	3.26	14	418		
3700	Sipunculus sp.	*Sipunculus* sp.	1	0.04	0	2		
4210	Whelks	*Buccinum* sp.	119	5.25	98	1174		
4211	Wave Whelk, Common Edible	*Buccinum undatum*	36	1.59	16	425		
4221	Northern Moonsnail	*Euspira heros*	100	4.41	44	437		
4227	New England Neptune	*Neptunea decemcostata*	9	0.4	7	120		
4228	Spindle Shell	*Colus* sp.	2	0.09	1	23		
4304	Ocean Quahaug	*Arctica islandica*	8	0.35	1	7		
4307	Astarte undata	*Astarte undata*	6	0.26	0	6		
4310	Clams (ns)	*Protobranchia, Heterodonta*	8	0.35	1	30		
4314	Morrhua venusna	*Pitar morrhuana*	2	0.09	0	2		
4317	Bar, Surf Clam	*Spisula solidissima*	1	0.04	0	1		
4318	Soft Shell Clam	*Mya arenaria*	1	0.04	0	1		
4319	Soft Shell or Long Neck Clam	*Hiatella arctica*	3	0.13	0	6		
4321	Sea Scallop	*Placopecten magellanicus*	499	22.01	3308	15999	8768	1839
4322	Iceland Scallop	*Chlamys islandica*	6	0.26	0	7	6	6
4331	Common Mussels	*Mytilus edulis*	1	0.04	1	14		
4332	Horse Mussels	*Modiolus modiolus*	7	0.31	5	30		
4334	Musculus niger	*Musculus niger*	1	0.04	0	2		
4343	Greenland Cockle	*Serripes groenlandicus*	2	0.09	0	2		
4400	Sea Slugs	Nudibranchia	5	0.22	0	9		
4511	Northern Shortfin Squid	*Illex illecebrosus*	387	17.07	1940	40850	12530	218
4512	Longfin Squid, Longfin Inshore	*Loligo pealeii*	25	1.1	83	1777	755	56
4521	Octopus	Octopoda	36	1.59	2	92		
4522	Semirossia tenera	*Semirossia tenera*	3	0.13	0	6		
4536	Bobtail Squid	Sepiolodae	7	0.31	0	13		
4541	Loligo sp.	*Loligo* sp.	14	0.62	24	905	905	7
4559	Pterygioteuthis sp.	*Pterygioteuthis* sp.	1	0.04	0	0		
4562	Octopoteuthis sp.	*Octopoteuthis* sp.	5	0.22	0	0		
5100	Sea Spider	Pycnogonida	1	0.04	0	12		
5200	Limpet (ns)	Archaeogastropoda	2	0.09	0	3		

Table 8. Continued

Species code	Common name	Scientific name	Number of sets occupied	Frequency (%) of sets occupied	Total weight (kg)	Total number	No. of individual lengths	No. of individual weights
6100	Asteroidea	Asteroidea	197	8.69	226	4781		
6101	Ceremaster granularis	*Ceremaster granularis*	2	0.09	0	3		
6102	Porania pulvilis	*Porania pulvilis*	4	0.18	3	33		
6109	Asterias forbesi	*Asterias forbesi*	4	0.18	2	51		
6110	Asterias sp.	*Asterias* sp.	120	5.29	74	1027		
6111	Asterias rubens	*Asterias rubens*	66	2.91	78	560		
6113	Leptasterias polaris	*Leptasterias polaris*	1	0.04	0	1		
6114	Leptasterias sp.	*Leptasterias* sp.	2	0.09	0	171		
6115	Mud Star	*Ctenodiscus crispatus*	9	0.4	3	34		
6116	Pseudarchaster sp.	*Pseudarchaster* sp.	4	0.18	0	21		
6117	Hippasteria phrygiana	*Hippasteria phrygiana*	9	0.4	1	18		
6119	Blood Star	*Henricia sanguinolenta*	29	1.28	1	167		
6120	Henrica sp.	*Henrica* sp.	18	0.79	2	87		
6121	Purple Sunstar	*Solaster endeca*	23	1.01	10	85		
6123	Spiny Sunstar	*Crossaster papposus*	75	3.31	17	364		
6125	Pteraster militaris	*Pteraster militaris*	3	0.13	0	3		
6129	Poraniomorpha hispida	*Poraniomorpha hispida*	3	0.13	0	8		
6131	Diplopteraster multipes	*Diplopteraster multipes*	4	0.18	1	32		
6200	Brittle Star	Ophiuroidea	17	0.75	7	31		
6212	Ophiura sp.	*Ophiura* sp.	1	0.04	0	13		
6300	Basket Stars	Gorgonocephalidae, Asteronychidae	1	0.04	0	1		
6400	Sea Urchins	*Strongylocentrotus* sp.	79	3.48	43	1794		
6411	Sea Urchin (Green)	*Strongylocentrotus droebachiensis*	98	4.32	51	1617		
6500	Sand Dollars	Clypeasteroida	133	5.87	201	9293		
6511	Echinarachnius parma	*Echinarachnius parma*	10	0.44	1	89		
6600	Sea Cucumber (unidentified)	Holothuroidea	49	2.16	61	192		
6611	Sea Cucumber (Common)	*Cucumaria frondosa*	19	0.84	21	92		
8100	Comb Jellies	Ctenophora	1	0.04	3	0		
8300	Sea Anemone	Anthozoa	30	1.32	11	148		
8327	Soft Coral unidentified	Soft coral unidentified	1	0.04	0	0		
8344	Staghorn Bryozoa	Hetropodidae	1	0.04	0	6		
8347	Psilaster andromeda	*Psilaster andromeda*	17	0.75	4	149		
8364	Geodia sp.	*Geodia* sp.	3	0.13	0	11		
8500	Jellyfishes	Scyphozoa	2	0.09	0	0		
8600	Sponges	Porifera	178	7.85	315	641		

Table 9. Number of otoliths or scales collected and aged by year for cod, haddock, pollock and yellowtail flounder sampled from the Georges Bank survey, 1987-2011.

Cod

Year	Otoliths collected	Otoliths Aged	% aged	Age Mean	Age Min	Age Max
1987	333	319	95.8	3	1	13
1988	971	453	46.7	4	1	13
1989	1068	500	46.8	4	1	13
1990	1372	1337	97.4	4	0	17
1991	1223	539	44.1	4	1	14
1992	923	453	49.1	4	1	13
1993	703	409	58.2	5	1	13
1994	464	413	89.0	4	1	13
1995	456	436	95.6	4	1	13
1996	814	514	63.1	4	1	13
1997	627	585	93.3	4	1	13
1998	580	557	96.0	4	1	13
1999	544	481	88.4	4	1	13
2000	572	553	96.7	5	1	13
2001	543	515	94.8	5	1	13
2002	738	715	96.9	5	1	13
2003	528	507	96.0	5	2	13
2004	422	412	97.6	5	1	13
2005	749	732	97.7	4	1	13
2006	691	651	94.2	5	2	13
2007	807	500	62.0	5	1	13
2008	542	519	95.8	5	1	13
2009	285	272	95.4	4	1	13
2010	449	436	97.1	5	1	13
2011	612	598	97.7	4	1	13

Haddock

Year	Otoliths collected	Otoliths Aged	% aged	Age Mean	Age Min	Age Max
1987	294	277	94.2	5	1	13
1988	961	638	66.4	4	1	17
1989	728	682	93.7	4	1	13
1990	1070	1052	98.3	4	1	15
1991	1049	1016	96.9	4	1	19
1992	657	639	97.3	3	1	14
1993	606	605	99.8	4	1	16
1994	466	464	99.6	3	1	16
1995	700	669	95.6	3	1	13
1996	991	960	96.9	4	1	13
1997	823	814	98.9	4	1	15
1998	1026	1014	98.8	4	1	15
1999	889	875	98.4	3	1	14
2000	1097	1086	99.0	4	1	13
2001	1076	1059	98.4	3	1	14
2002	1527	873	57.2	4	1	15
2003	1177	1130	96.0	4	1	12
2004	1357	1337	98.5	4	1	14
2005	1292	1226	94.9	5	1	14
2006	1782	985	55.3	4	1	15
2007	1215	672	55.3	4	1	16
2008	1042	629	60.4	5	1	12
2009	557	550	98.7	5	1	13
2010	799	795	99.5	6	1	13
2011	1494	599	40.1	6	1	14

Pollock

Year	Otoliths collected	Otoliths Aged	% aged	Age Mean	Age Min	Age Max
1987	118	102	86.4			
1988	269	0				
1989	218	214	98.2	5	2	13
1990	132	128	97.0	6	2	14
1991	199	192	96.5	4	1	15
1992						
1993	21	0				
1994	44	31	70.5	5	2	14
1995	45	0				
1996	71	0				
1997	58	0				
1998	71	0				
1999	18	0				
2000	85	0				
2001	42	0				
2002	159	0				
2003	193	0				
2004	98	0				
2005	135	0				
2006	99	0				
2007	55	0				
2008	56	0				
2009	11	0				
2010	13	0				
2011	113	0				

Yellowtail Flounder

Year	Scales collected	Scales Aged	% aged	Age Mean	Age Min	Age Max
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
1996						
1997						
1998						
1999						
2000						
2001						
2002						
2003						
2004	562	337	60.0	4	1	9
2005	509	417	81.9	4	1	10
2006	514	474	92.2	3	2	7
2007	709	574	81.0	3	1	7
2008	508	466	91.7	3	2	6
2009	247	198	80.2	4	1	7
2010	385	367	95.3	4	2	7
2011	359	330	91.9	4	1	7

Table 10. Minimum and maximum tow depth (m) by stratum recorded on the ships sounder from the Georges Bank survey, all years combined (1987-2011).

Strata	Stratum depth range (m)	No. of sets	Tow depth (m)					
			Minimum			Maximum		
			Mean	Min	Max	Mean	Min	Max
5Z1	93-183	288	112.8	72.8	180.2	119.5	87.4	196.6
5Z2	<93	763	75.5	38.2	96.5	78.9	56.4	116.5
5Z3	0-183	312	61.2	23.7	178.4	65.5	29.1	183.8
5Z4	<93	342	65.6	23.7	92.8	68.2	36.4	96.5
5Z5	93-183	125	146.5	91.0	183.8	153.8	96.5	185.6
5Z6	<93	200	58.4	21.8	91.0	62.4	29.1	92.8
5Z7	<93	142	63.2	23.7	91.0	66.6	27.3	91.0
5Z8	93-183	89	115.8	89.2	192.9	121.9	92.8	212.9
5Z9 (2010-present)	>183	5	226.0	198.4	251.2	233.3	202.0	260.3

Table 11. Number of sets by stratum where hydrographic data was collected during the Georges Bank surveys, 1987-2011. Grey shading indicates years and strata which were not sampled due to time constraints from inclement weather or mechanical problems. (% = Total Hydros/Total fishing sets).

Year	Stratum								Total hydros	Total fishing sets	%
	5Z1	5Z2	5Z3	5Z4	5Z5	5Z6	5Z7	5Z8			
1987	8	7	7	11	9	5	12	8	67	68	99
1988	24	28	16	16	12	11	14	10	131	132	99
1989	18	25	12	15	12	9	16	9	116	116	100
1990	23	22	14	16	13	8	17	10	123	123	100
1991	18	23	13	17	11	14	16	10	122	132	92
1992	10	30	9	15	3	10	5	3	85	91	93
1993	10	36	11	6				2	65	65	100
1994	6	24	9	4					43	45	96
1995	9	31	11	12	5	10	4	2	84	85	99
1996	9	33	12	12	4	9	3	1	83	86	97
1997	9	32	11	15	5	11	4	3	90	90	100
1998	9	37	16	13	5	9	4	2	95	96	99
1999	4	11	4	7	1	4	4	3	38	82	46
2000	5	10	7	8	4	6	3	3	46	100	46
2001	7	18	6	7	2	3	2	3	48	76	63
2002	6	17	3	7	2	7	2	3	47	89	53
2003	4	10	7	4	2	3	2	2	34	98	35
2004	5	9	5	5	1	3	1	2	31	85	36
2005	1	3	4	3	2	3	3	1	20	131	15
2006	5	12	4	7					28	92	30
2007	8	12	2	6	1	5	3		37	88	42
2008	7	11	4	4	2	2	2	1	33	69	48
2009	5	10	4	3	2	1	3		28	68	41
2010	5	13	6	5	1			1	31	63	49
2011	6	16	10	4	2	2	2	1	43	97	44
ratum total	213	473	200	211	92	130	110	72	1568	2267	69

Table 12. Comparison of the 2011 Georges bank survey biomass estimates for selected fish and invertebrate species with the short term (2006-2010; "s"), medium term (1995-2010; "m"), and the long term average (1987-2010; "l"). When the direction is "up", 2011 > s, m, l and when direction is "down", 2011 < s, m, l; "nt" indicates no consistent trend.

	Total biomass (t)				Direction
Species	2011	2006-2010 average (s)	1996-2010 average (m)	1987-2010 average (l)	(2011 vs s, m, l)
Atlantic cod	8375	18512	17727	19467	down
Haddock	63822	91719	71840	52588	nt
Pollock	12940	4173	5192	5924	up
Yellowtail Flounder	3830	33486	20399	13421	down
American Plaice	210	444	651	614	down
Winter Flounder	264	316	997	1063	down
Brill/Windowpane	855	1498	1944	2015	down
Fourspot Flounder	237	128	158	133	up
Atlantic halibut	137	73	48	63	up
Longhorn Sculpin	742	1895	7332	9019	down
Sea Raven	1441	1452	1837	1744	down
Ocean pout	87	144	640	1699	down
Monkfish	20	40	109	120	down
Redfish	30	12	19	30	up
White Hake	25	31	89	96	down
Red Hake	277	1347	659	580	down
Silver Hake	1378	1197	1752	1817	nt
Cusk	13	12	25	49	nt
Striped Atlantic Wolffish	11	16	158	307	down
Atlantic herring	1315	235	5060	4350	nt
Atlantic mackerel	152	307	1454	1001	down
Spiny Dogfish	0	742	3819	18971	down
Winter Skate	4491	7879	10588	14413	down
Little Skate	2279	5450	7434	7353	down
Barndoor Skate	292	107	192	152	up
Thorny Skate	72	55	125	188	nt
Smooth Skate	14	14	12	12	up
American Lobster	1863	826	628	464	up
Sea Scallop*	3609	1669	1911	1752	up
Shortfin Squid	25	170	135	148	down

* Time series begins in 2000

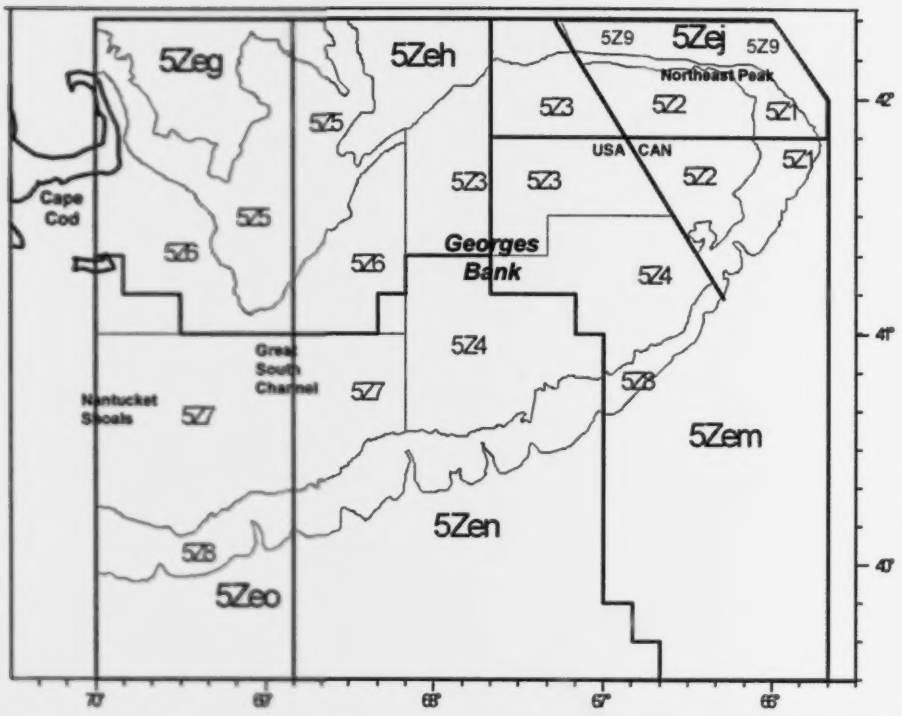


Figure 1. Georges Bank survey strata (5Z1/5Z9; green) and NAFO unit areas (5Zeg-5Zeo; red). Strata 5Z1-5Z8 have been sampled since 1987, stratum 5Z9 was added to the survey program in 2010. The Canada/USA international boundary is shown in blue.

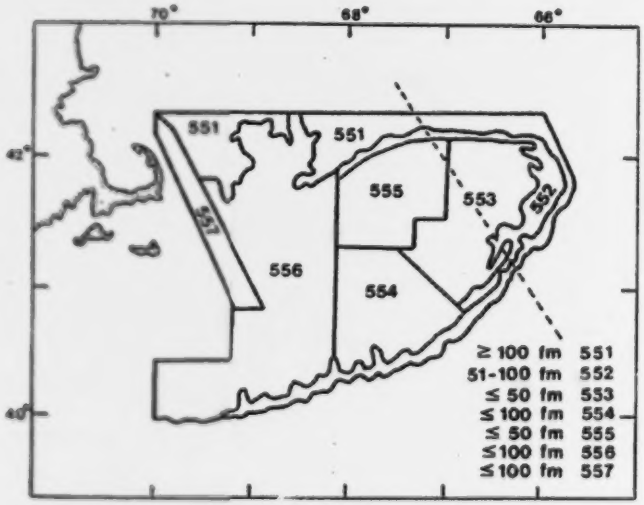


Figure 2. Stratification scheme used for the 1986 Georges Bank survey (from Gavaris and Walwood 1986).

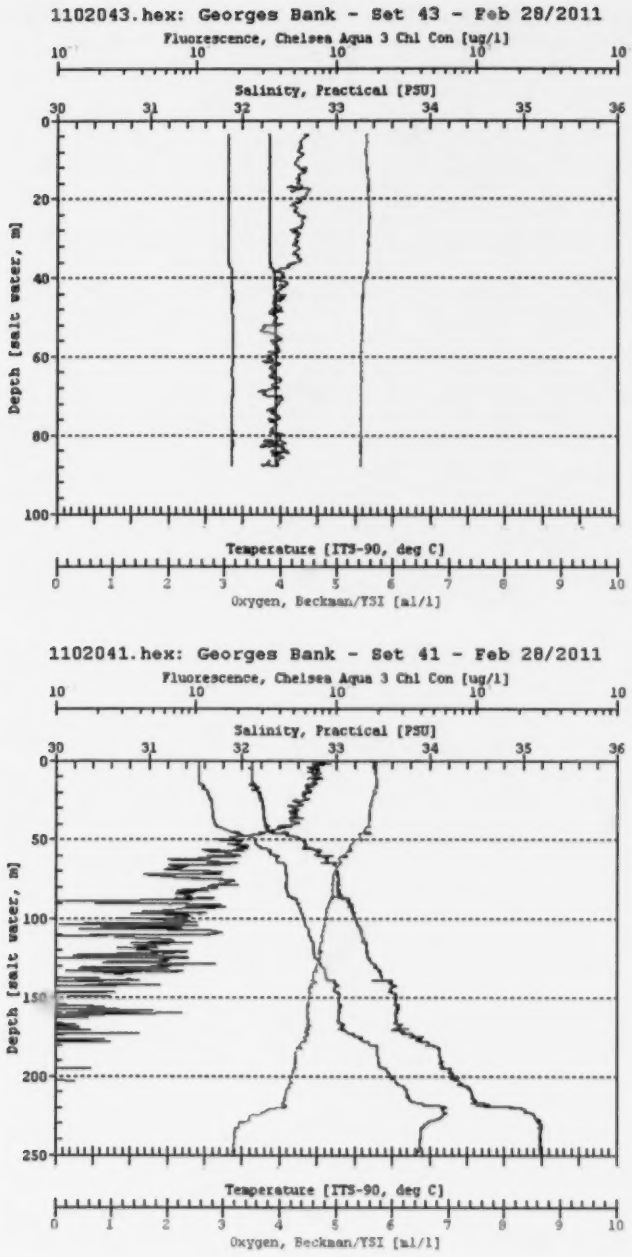

1102043.hex: Georges Bank - Set 43 - Feb 28/2011
Fluorescence, Chelsea Aqua 3 Chl Con [ug/l]
Salinity, Practical [PSU]
Depth [salt water, m]
Temperature [ITS-90, deg C]
Oxygen, Beckman/YSI [ml/l]
1102041.hex: Georges Bank - Set 41 - Feb 28/2011
Fluorescence, Chelsea Aqua 3 Chl Con [ug/l]
Salinity, Practical [PSU]
Depth [salt water, m]
Temperature [ITS-90, deg C]
Oxygen, Beckman/YSI [ml/l]

Figure 3. Profiles of temperature (°C), salinity (parts per thousand; ppt), chlorophyll concentration (ug/l) and oxygen level (ml/l) for a CTD cast in shallow water (80 m) on top of the Georges Bank in stratum 5Z2 (upper panel) and for a cast in deeper water (250 m) along the edge of the bank in Stratum 5Z1 (lower panel), February 2011.

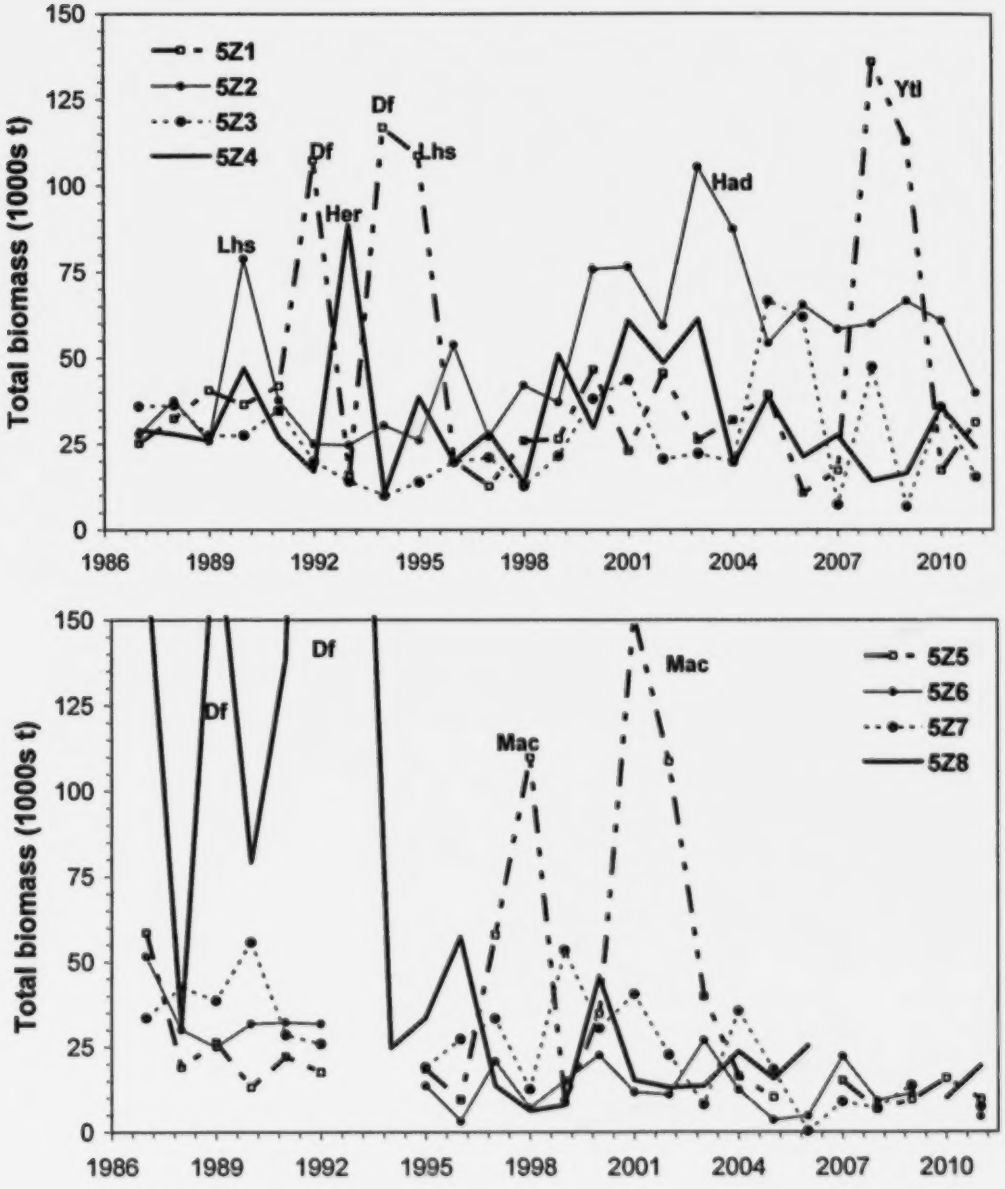


Figure 4. Annual estimates of total stratified biomass (1000s t) from the Georges Bank survey for strata 5Z1-5Z4 (upper panel) and 5Z5-5Z8 (lower panel), 1987-2011. Species which made a large contribution to peaks total biomass in a given year are indicated (Lhs: longhorn sculpin; Df: dogfish; Her: herring; Had: haddock; Ytl: yellowtail flounder; Mac: mackerel)

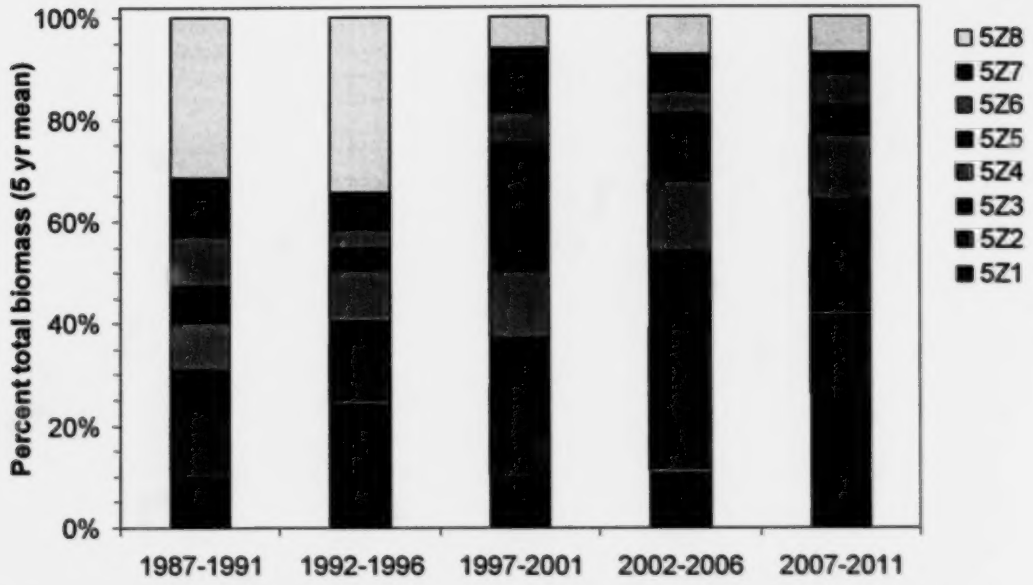


Figure 5. Five-year mean percentage of total survey biomass represented by each of the eight survey strata (5Z1-5Z8) from the Georges Bank survey, 1987-2011.

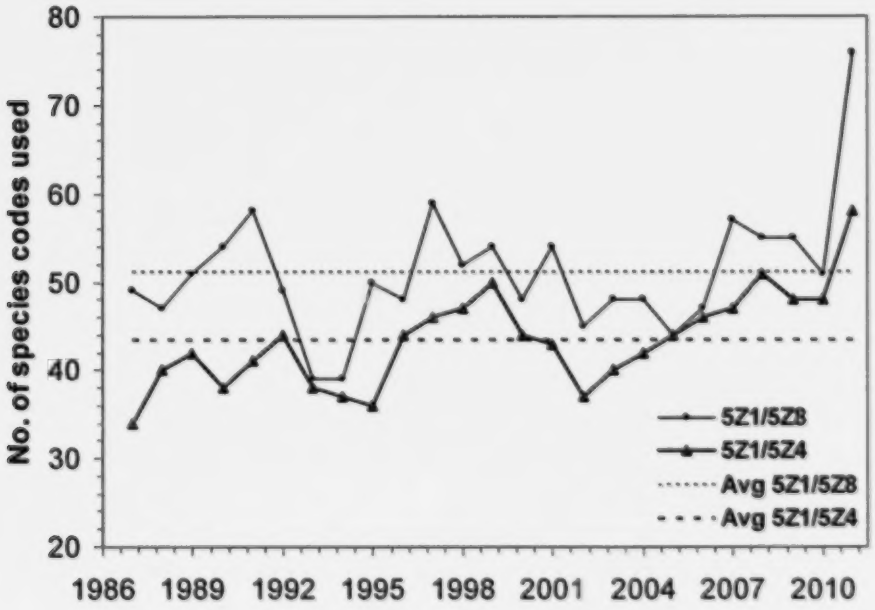


Figure 6. Number of species codes used for all strata (5Z1-5Z8) and those used for TRAC assessments (5Z1-5Z4) from the Georges Bank survey, 1987-2011.

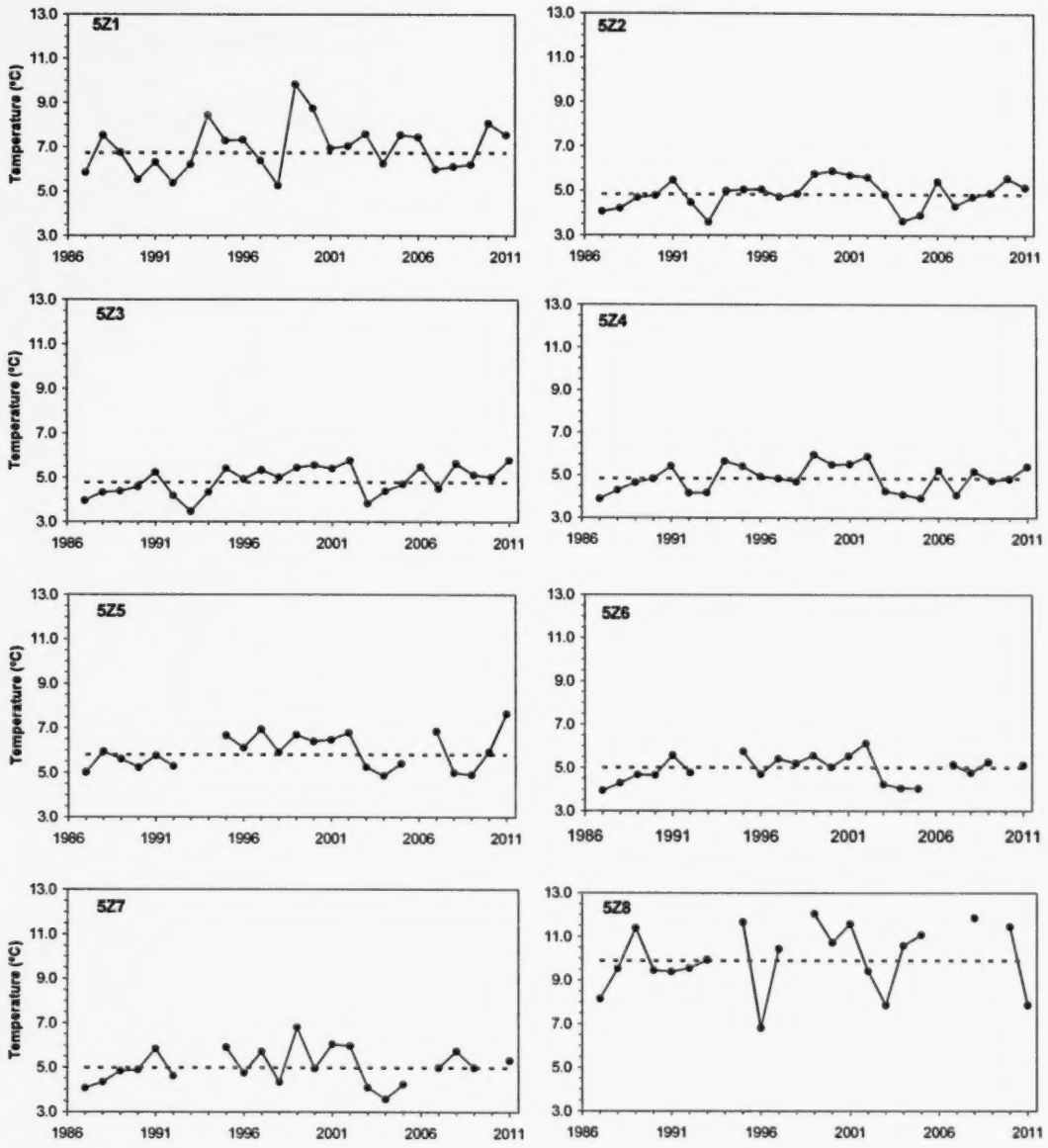


Figure 7. Annual mean bottom temperature (^{o}C) by stratum (5Z1-5Z8) for the Georges Bank survey, 1987-2011. The dashed line is the mean for the entire time series.

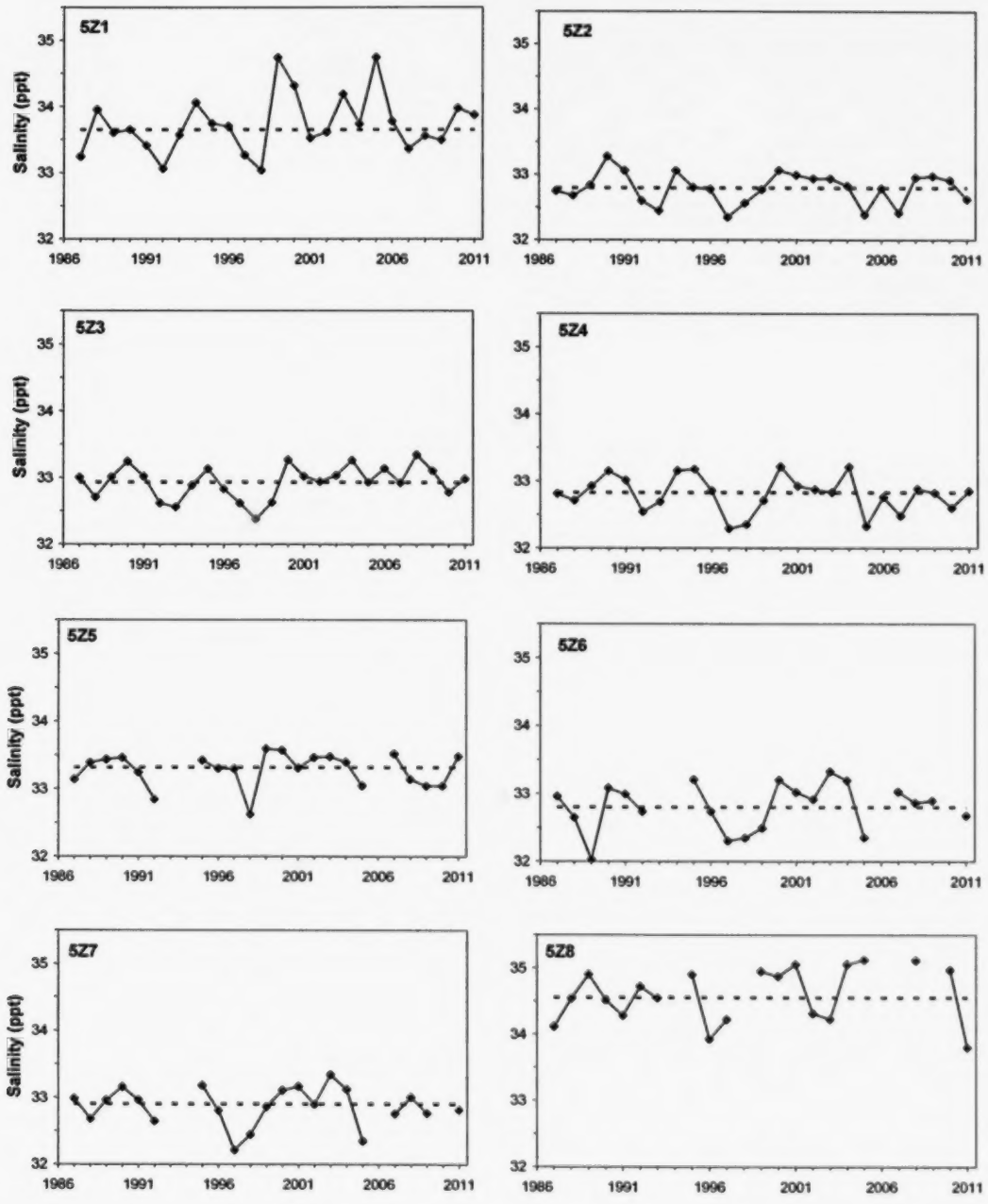


Figure 8. Annual mean bottom salinity (ppt) by stratum (5Z1-5Z8) for the Georges Bank survey, 1987-2011. The dashed line is the mean for the entire time series.

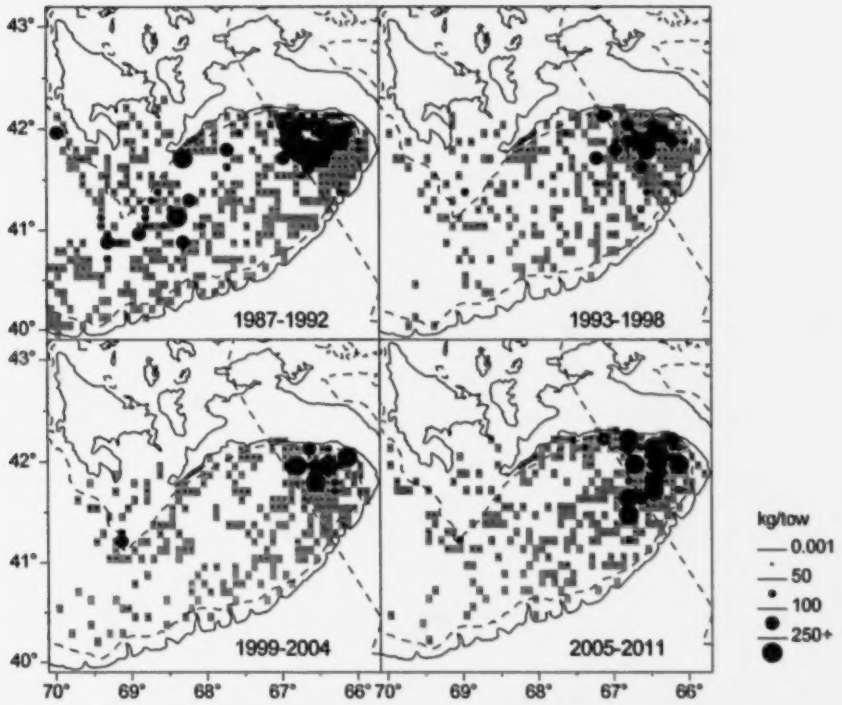


Figure 9. Distribution of Atlantic cod catches (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

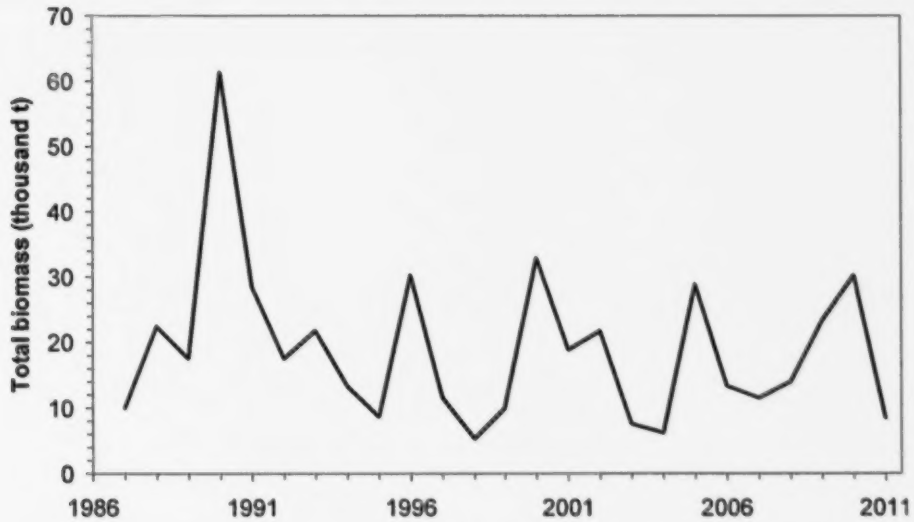


Figure 10. Total biomass estimates of Atlantic cod from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

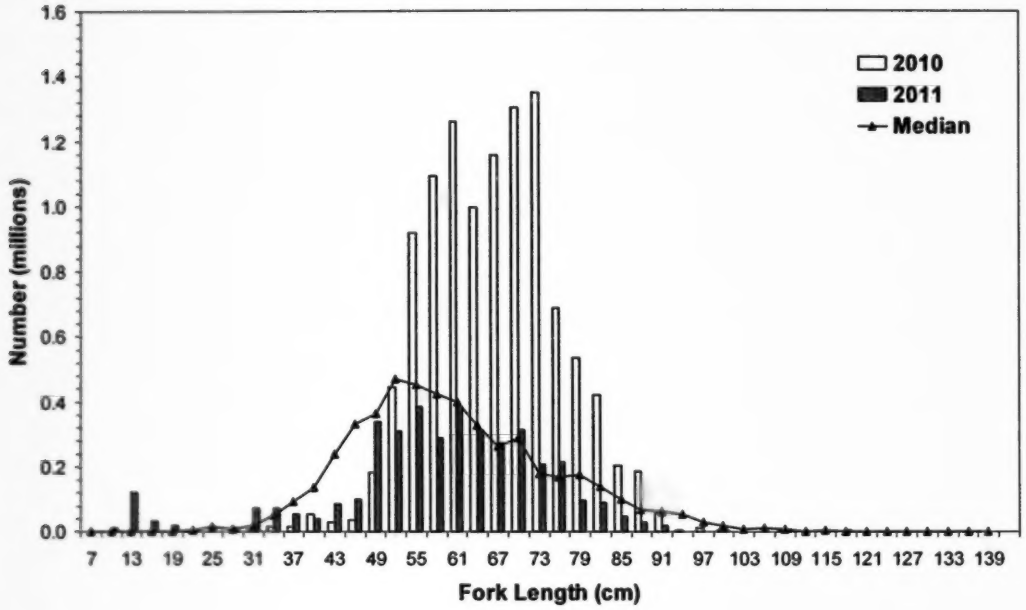


Figure 11. Length stratified total number (millions) for Atlantic cod from Georges Bank Survey strata 5Z1-5Z4 for 2010 and 2011 compared to the median for 1987-2009.

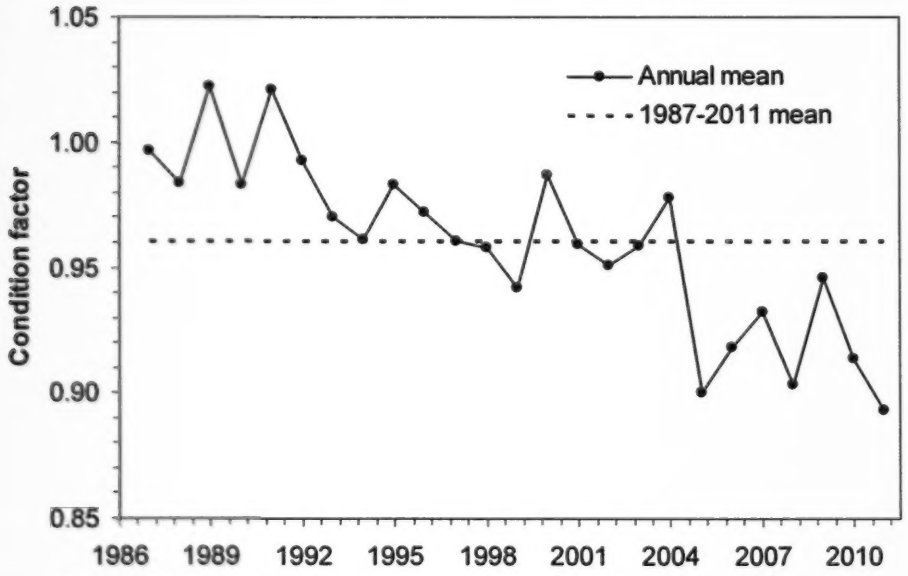


Figure 12. Annual mean condition factor (Fulton's K) for Atlantic cod (30-80 cm FL) compared to the long-term mean from Georges Bank survey strata 5Z1-5Z8, 1987-2011.

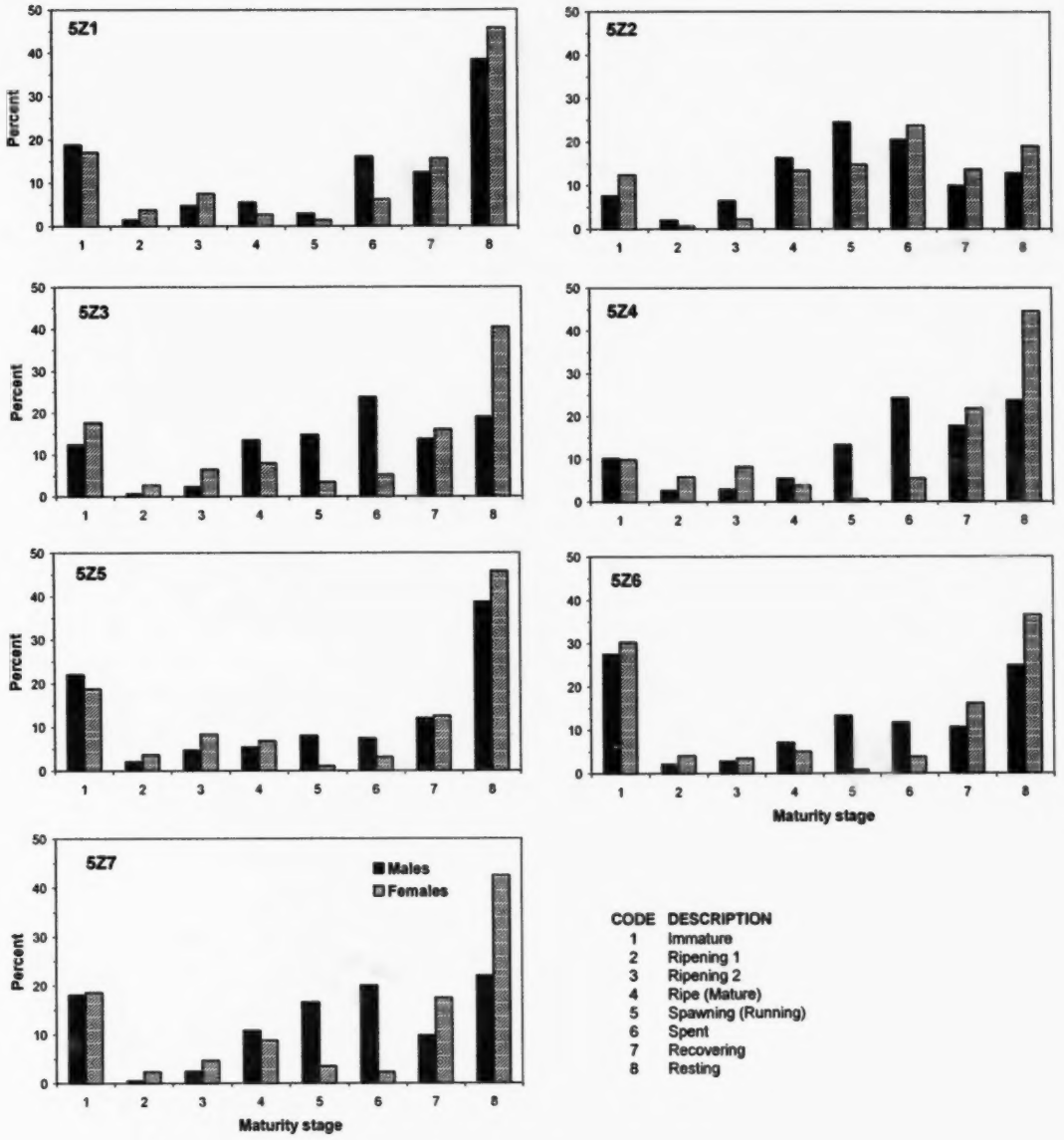


Figure 13. Maturity stages of Atlantic cod by strata (5Z1-5Z7) for all years combined from the Georges Bank survey, 1987-2011. Too few observations were available for 5Z8.

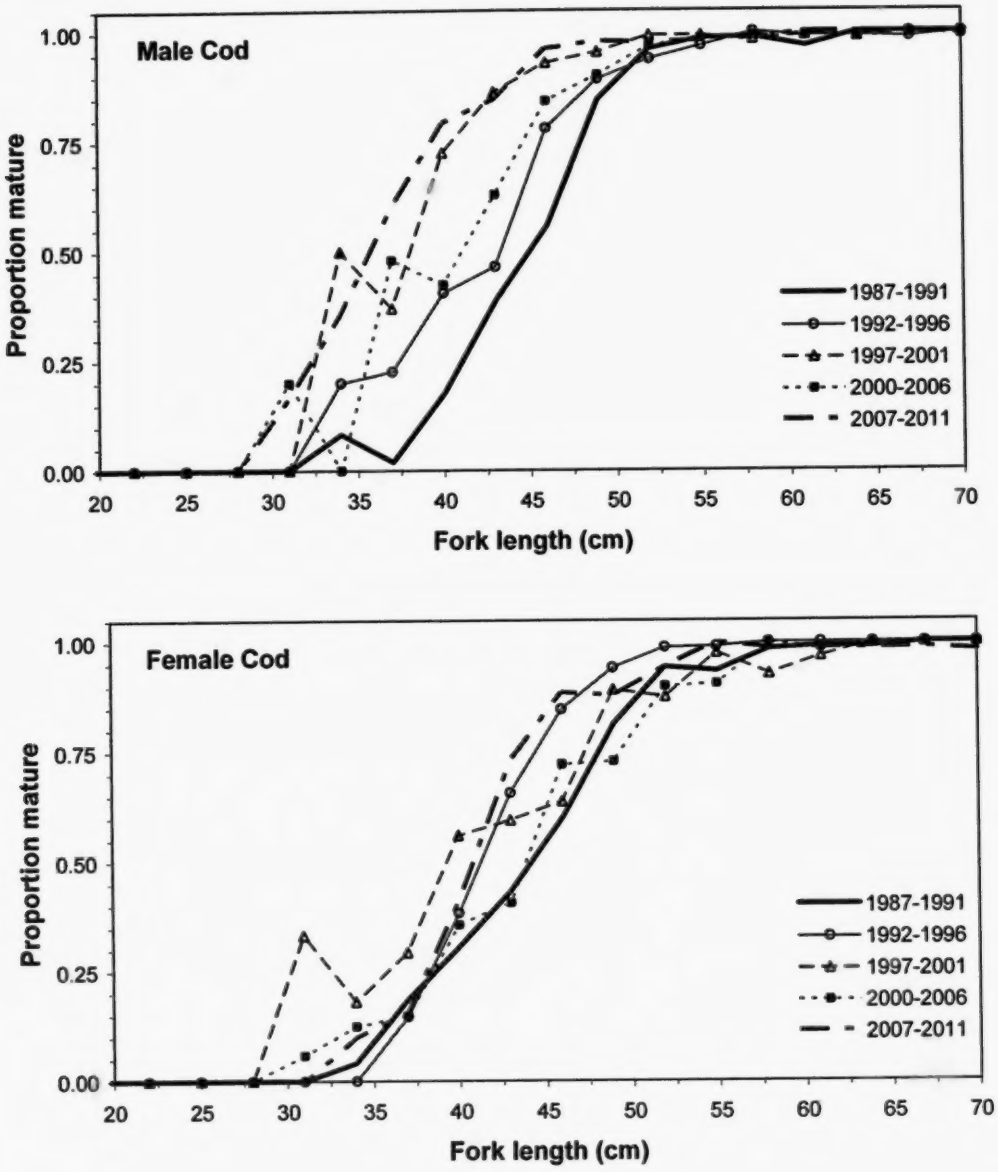


Figure 14. Proportion mature (stages 2-8) at length for Atlantic cod from Georges Bank survey strata 5Z1-5Z4, 1987-2011. Maturity data has been aggregated into 5 year blocks. This analysis was based on sampled fish and was not scaled to population level.

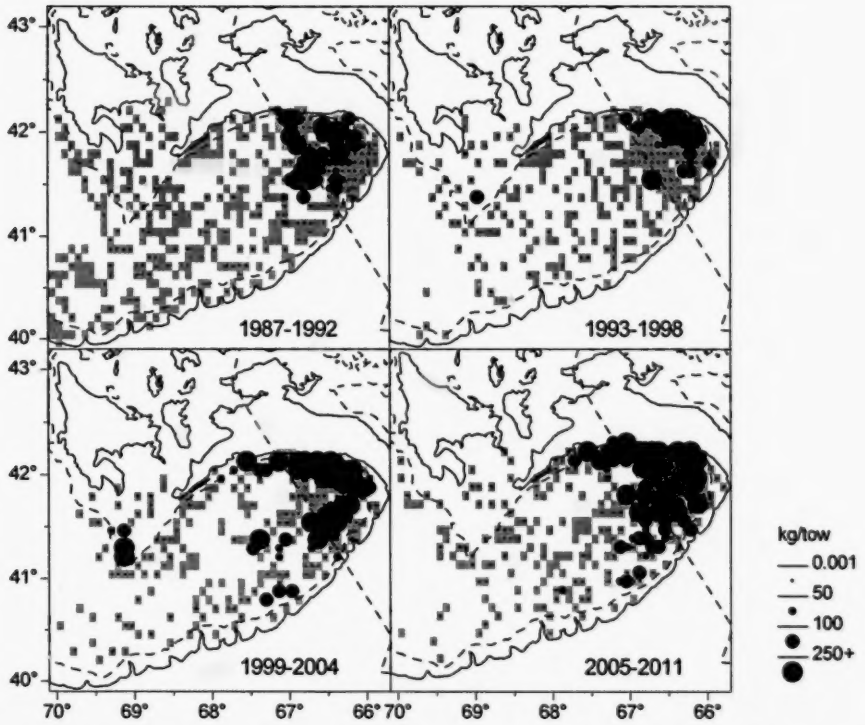


Figure 15. Distribution of haddock catches (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

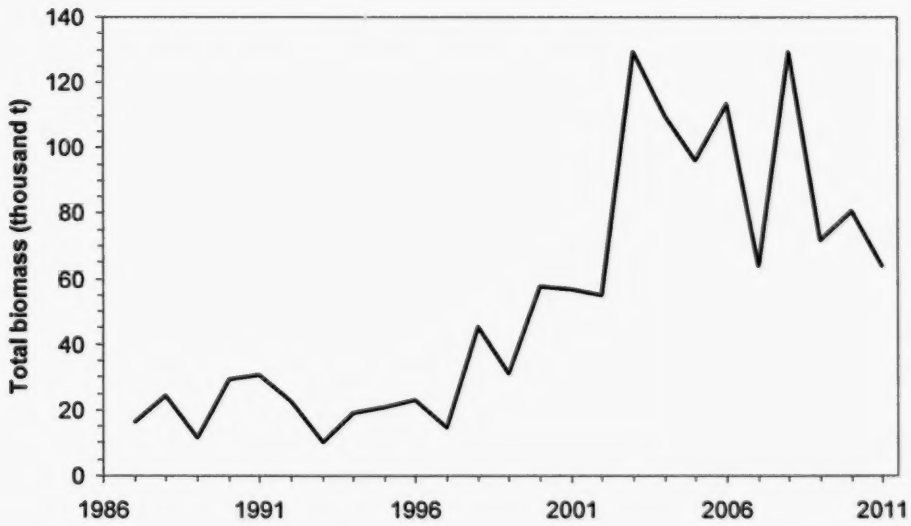


Figure 16. Total biomass estimates of haddock from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

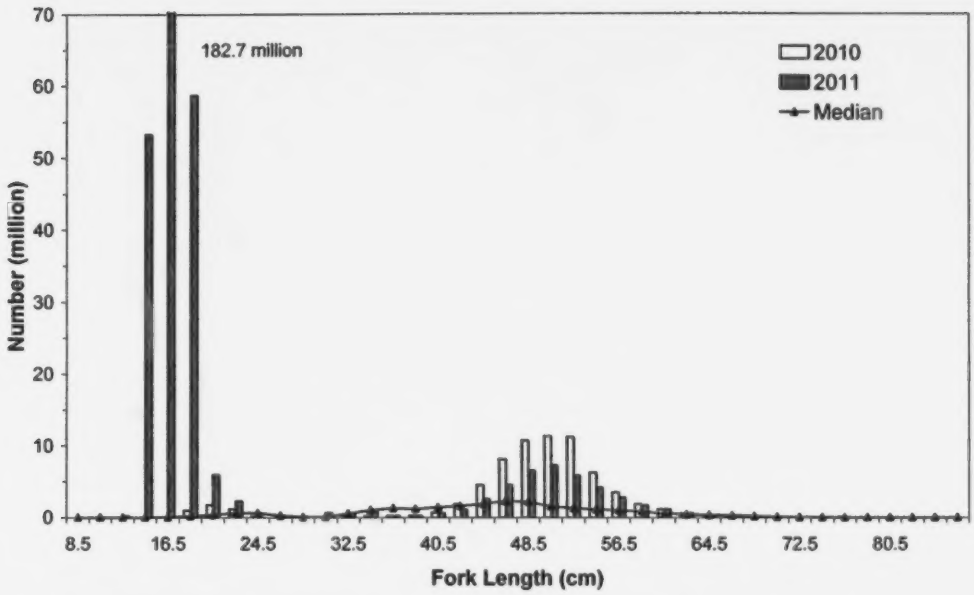


Figure 17. Length stratified total number (millions) for haddock from Georges Bank Survey strata 5Z1-5Z4 for 2010 and 2011 compared to the median for 1987-2009. Numbers at 16.5 cm peaked at 183 million.

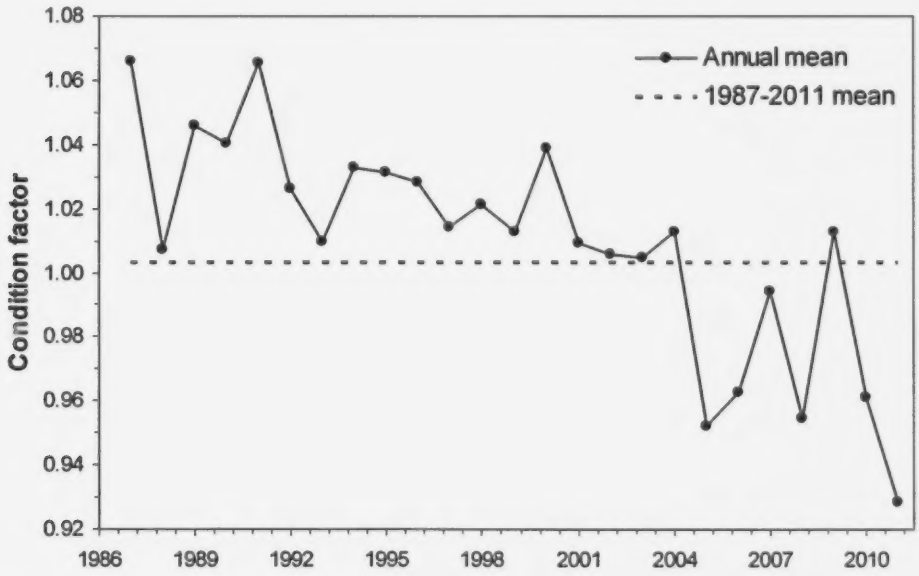
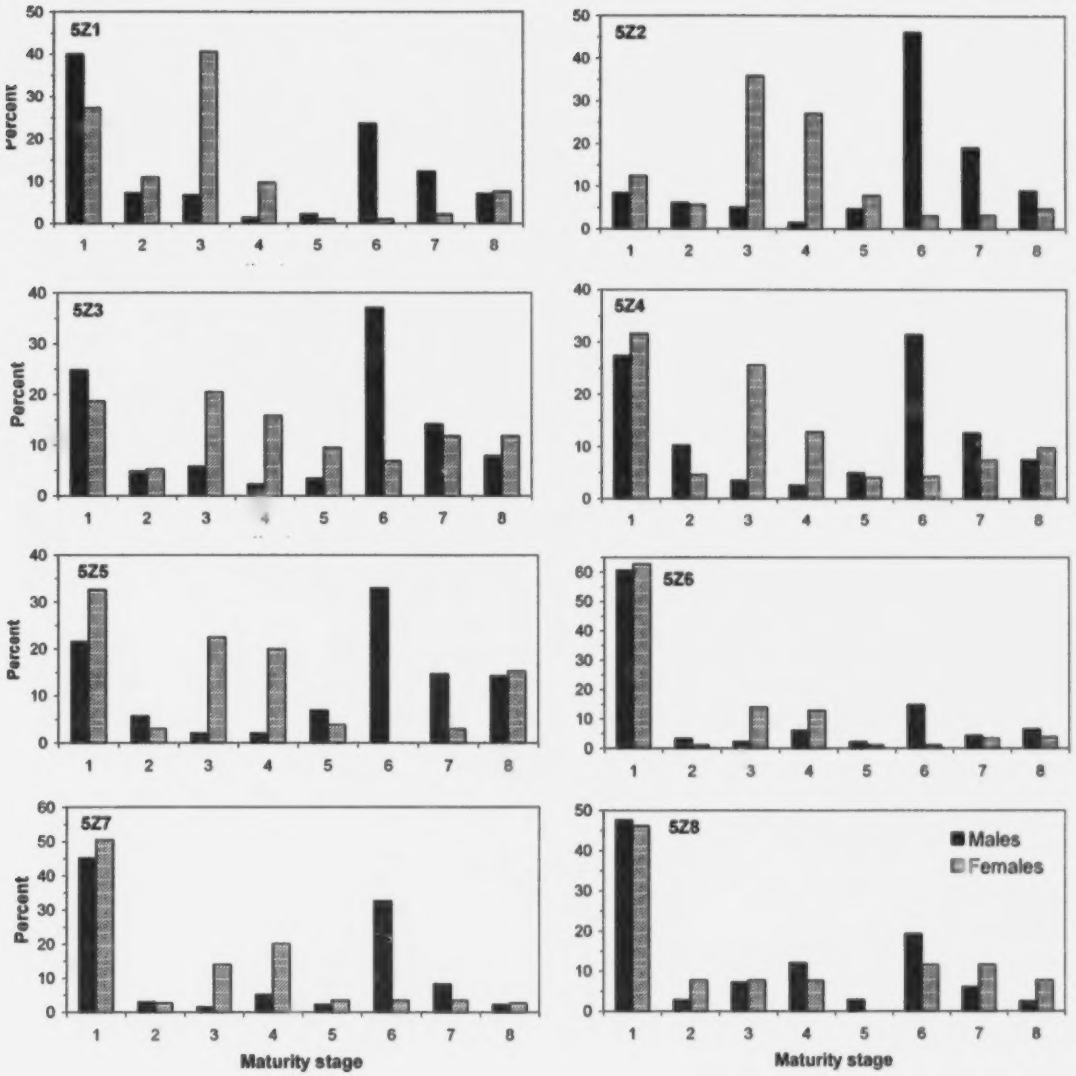


Figure 18. Annual mean condition factor (Fulton's K) for haddock (30-70 cm FL) compared to the long-term mean from Georges Bank survey strata 5Z1-5Z8, 1987-2011.



CODE	DESCRIPTION
1	Immature
2	Ripening 1
3	Ripening 2
4	Ripe (Mature)
5	Spawning (Running)
6	Spent
7	Recovering
8	Resting

Figure 19. Maturity stages of haddock by strata (5Z1-5Z8) for all years combined from the Georges Bank survey, 1987-2011.

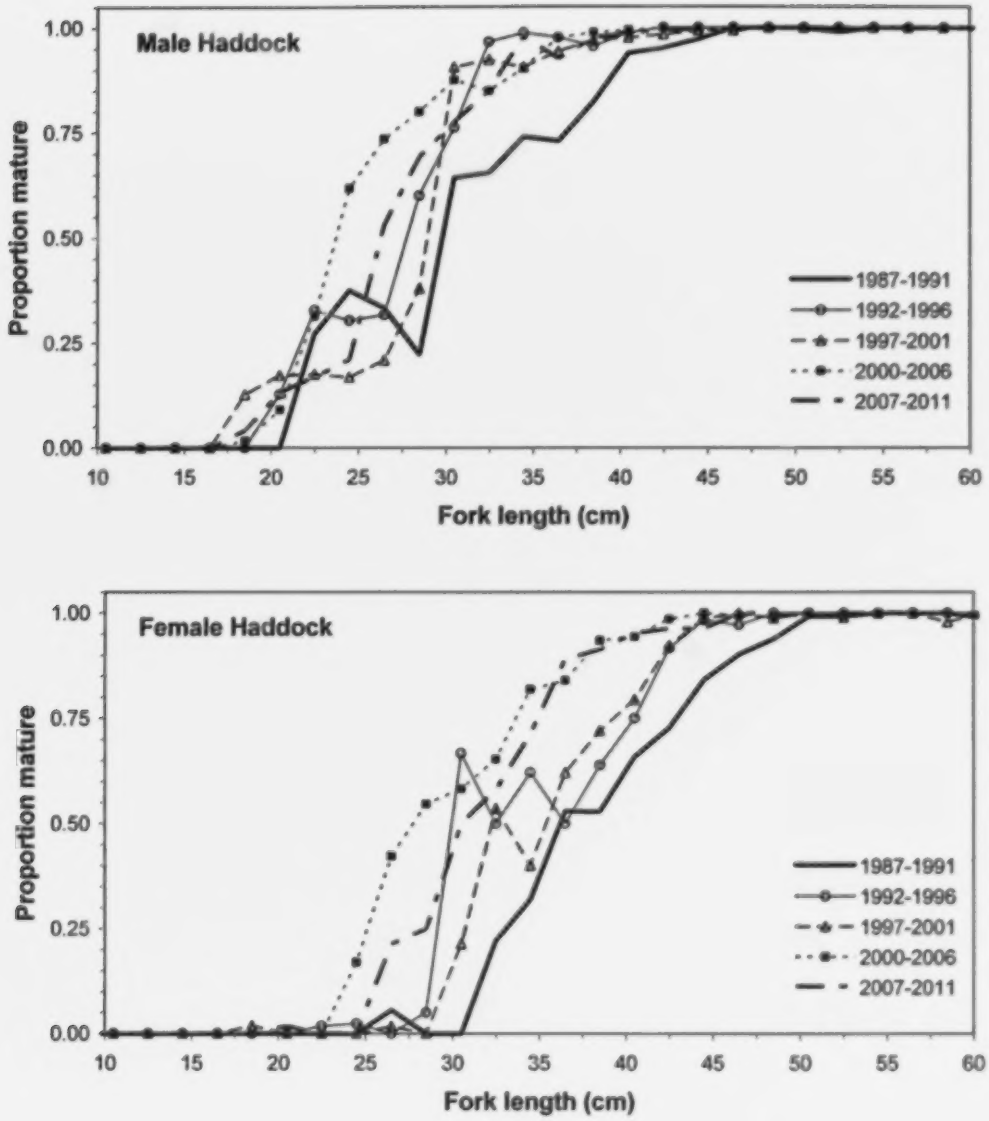


Figure 20. Proportion mature (stages 2-8) at length for haddock from Georges Bank survey strata 5Z1-5Z4, 1987-2011. Maturity data has been aggregated into 5 year blocks. This analysis was based on sampled fish and was not scaled to population level.

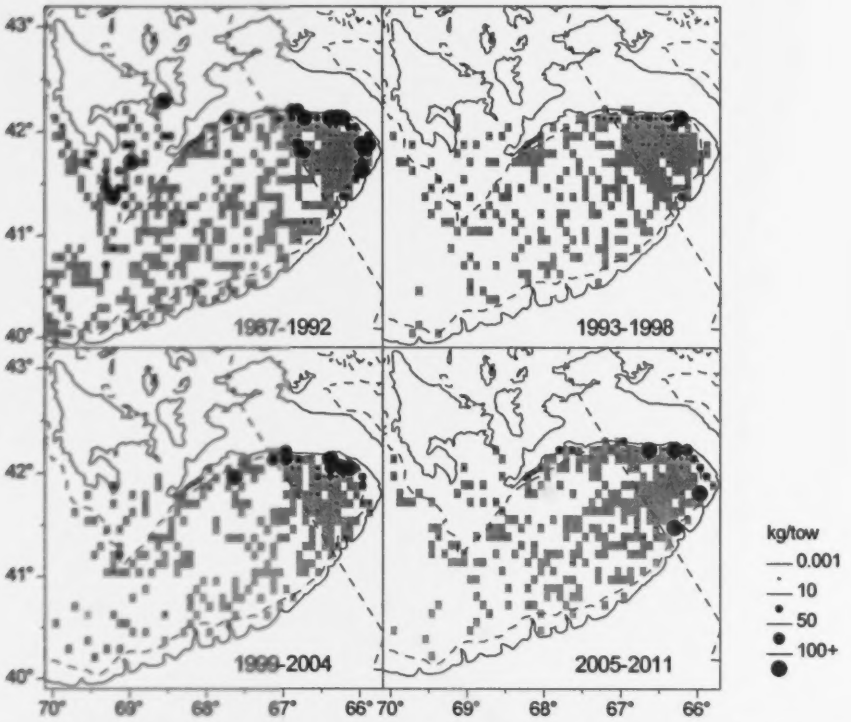


Figure 21. Distribution of pollock catches (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

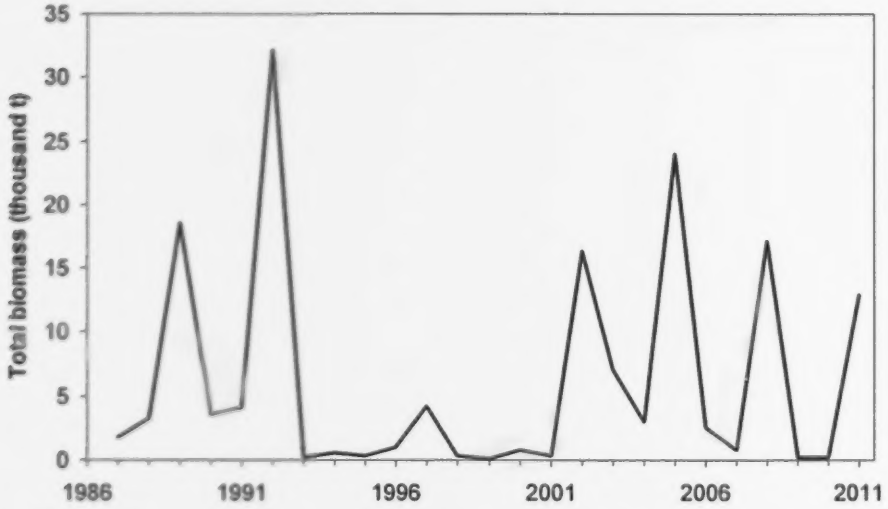


Figure 22. Total biomass estimates of pollock from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

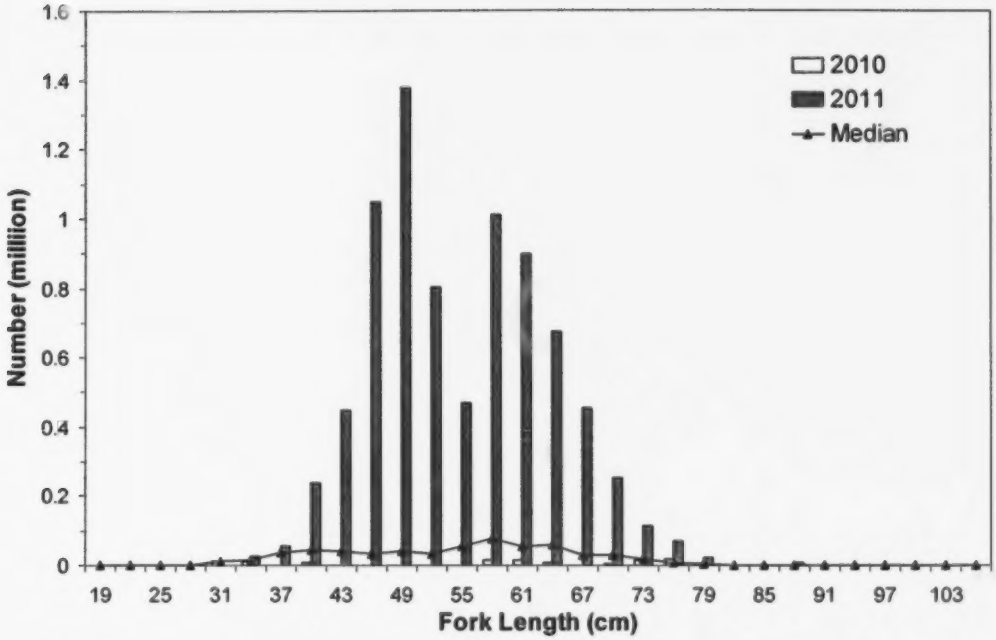


Figure 23. Length stratified total number (millions) for pollock from Georges Bank Survey strata 5Z1-5Z4 for 2010 and 2011 compared to the median for 1987-2009.

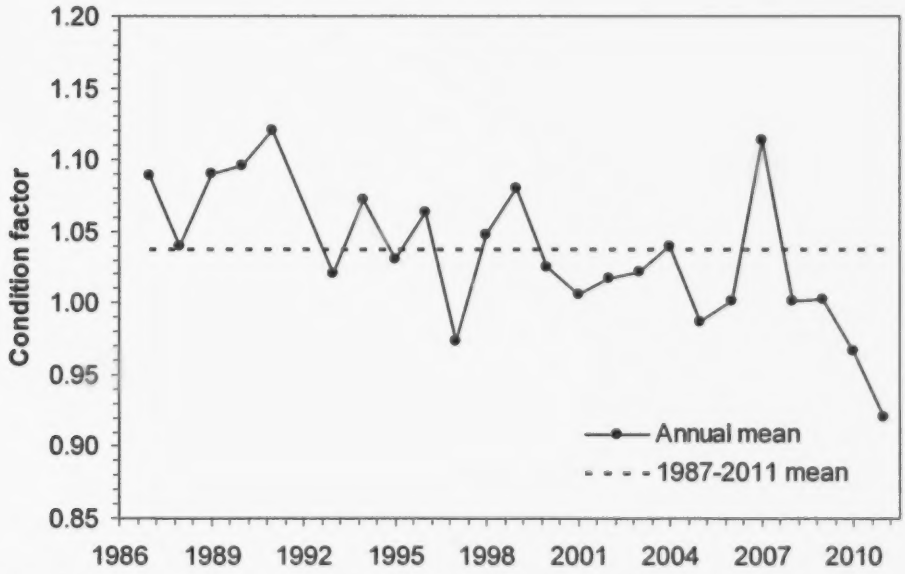


Figure 24. Annual mean condition factor (Fulton's K) for pollock (30-80 cm FL) compared to the long-term mean from Georges Bank survey strata 5Z1-5Z8, 1987-2011.

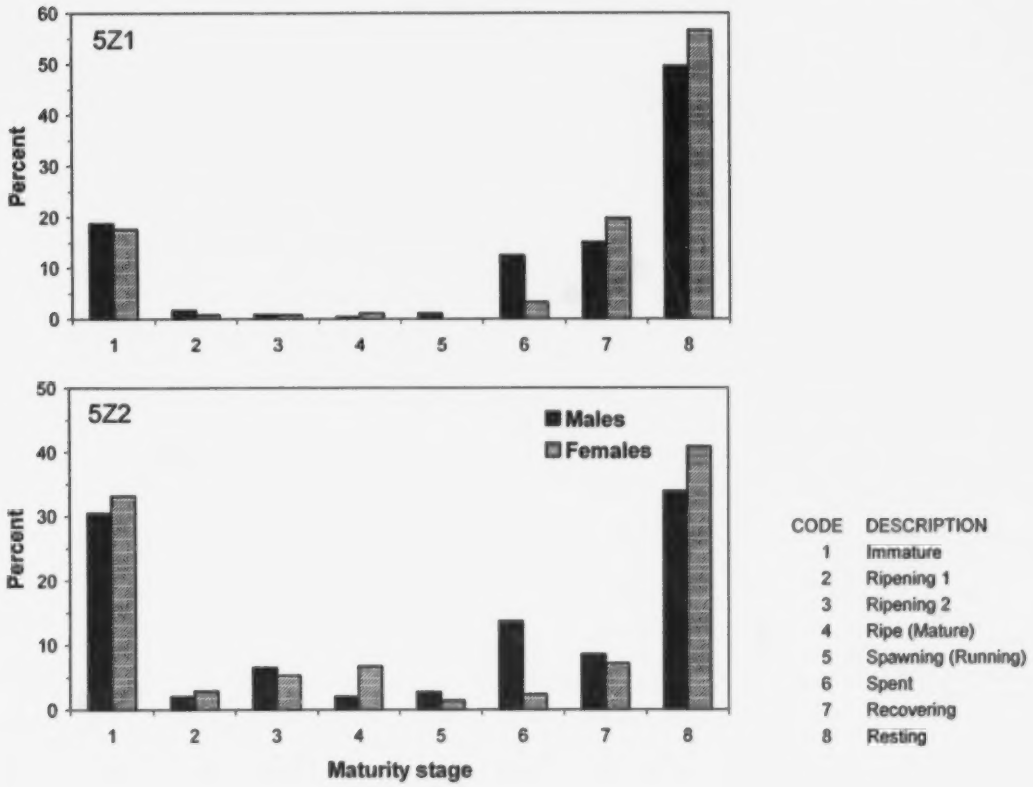


Figure 25. Maturity stages of pollock by strata (5Z1 and 5Z2) for all years combined from the Georges Bank survey, 1987-2011.

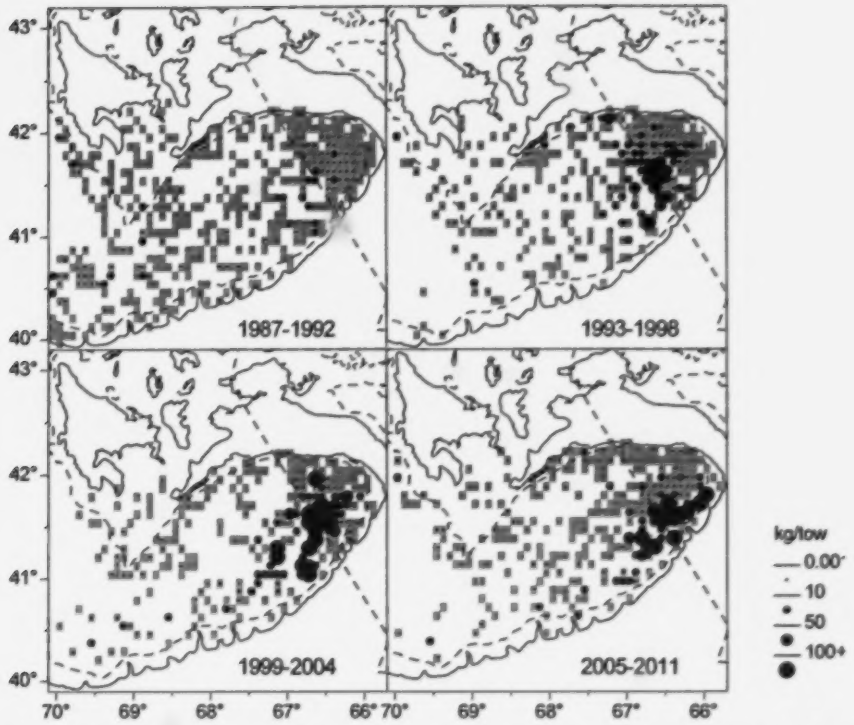


Figure 26. Distribution of yellowtail flounder catches (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates areas extent of area surveyed. The solid line indicates the international boundary.

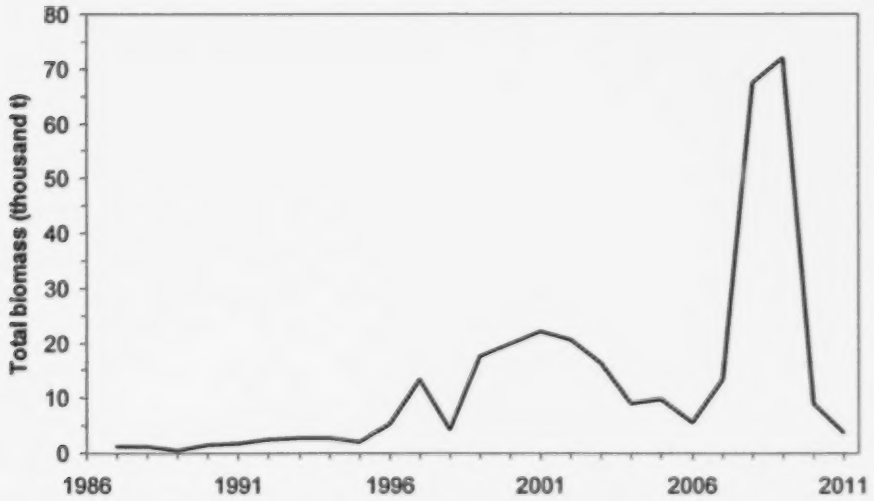


Figure 27. Total biomass estimates of yellowtail flounder from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

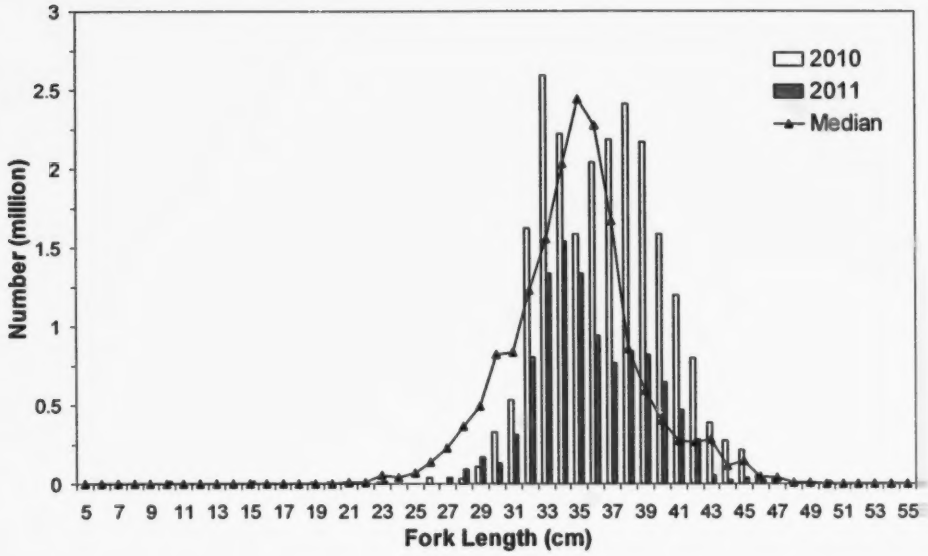


Figure 28. Length stratified total number (millions) for yellowtail flounder from Georges Bank Survey strata 5Z1-5Z4 for 2010 and 2011 compared to the median for 1987-2009.

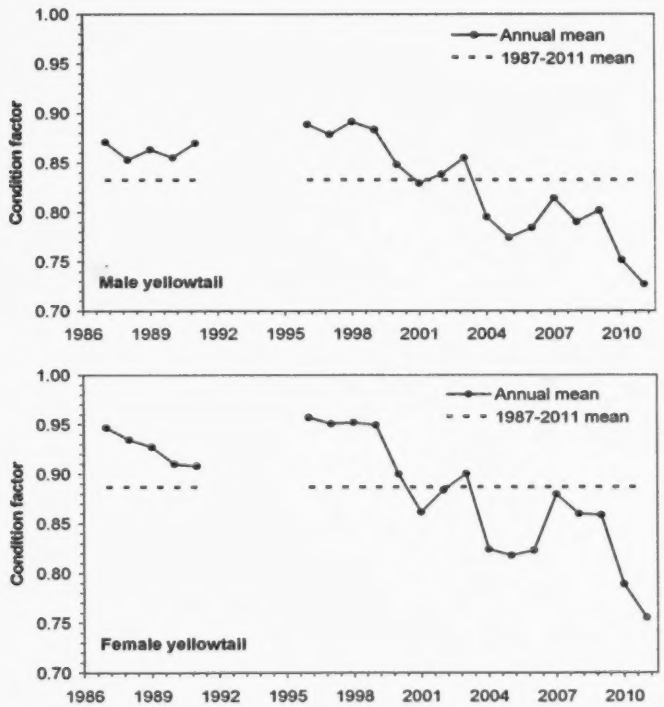
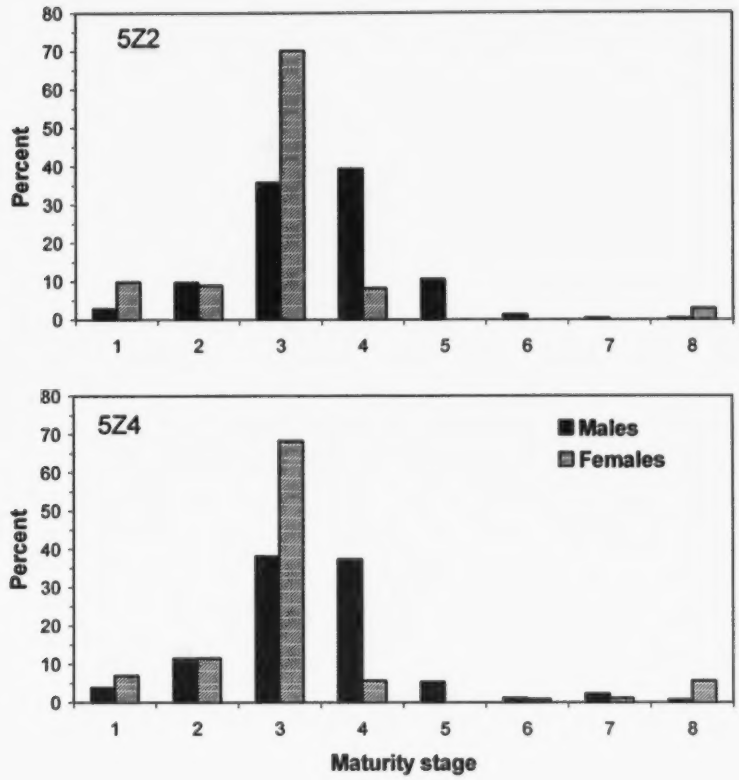


Figure 29. Annual mean condition factor (Fulton's K) for for male and female yellowtail flounder (25-40 cm FL) compared to the long-term mean from Georges Bank survey strata 5Z1-5Z8, 1987-2011.



CODE	DESCRIPTION
1	Immature
2	Ripening 1
3	Ripening 2
4	Ripe (Mature)
5	Spawning (Running)
6	Spent
7	Recovering
8	Resting

Figure 30. Maturity stages of yellowtail flounder by strata (5Z2 and 5Z4) for all years combined from the Georges Bank survey, 1987-2011.

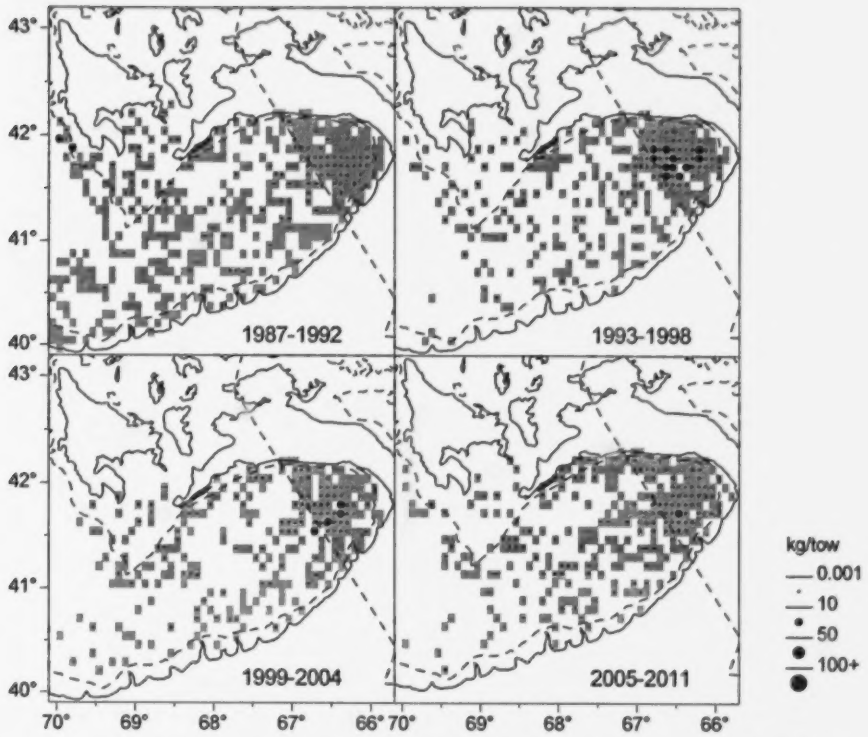


Figure 31. Distribution of American plaice catches (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

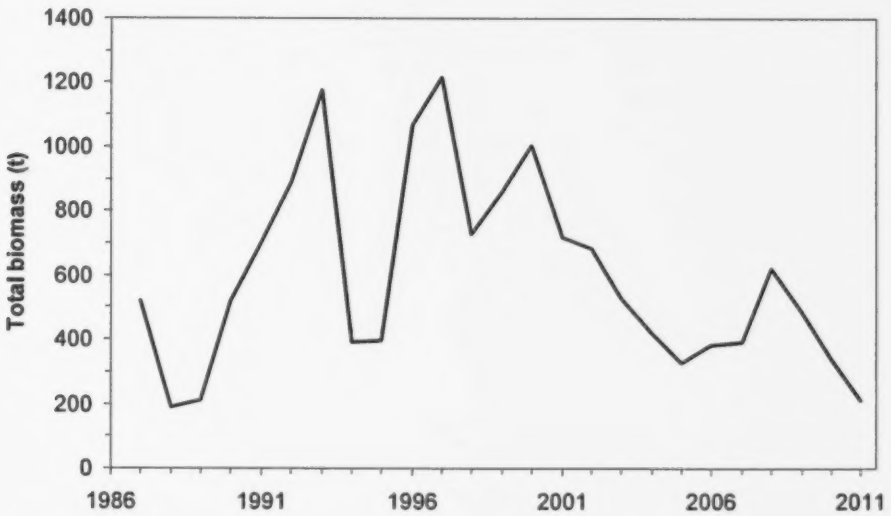


Figure 32. Total biomass estimates of American plaice from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

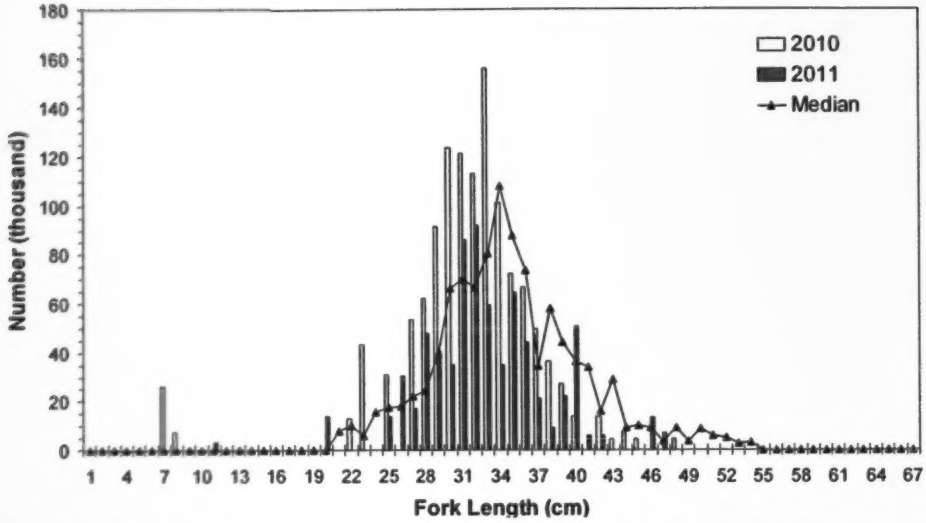


Figure 33. Length stratified total number (thousands) for American Plaice from Georges Bank Survey strata 5Z1-5Z4 for 2010 and 2011 compared to the median for 1987-2009.

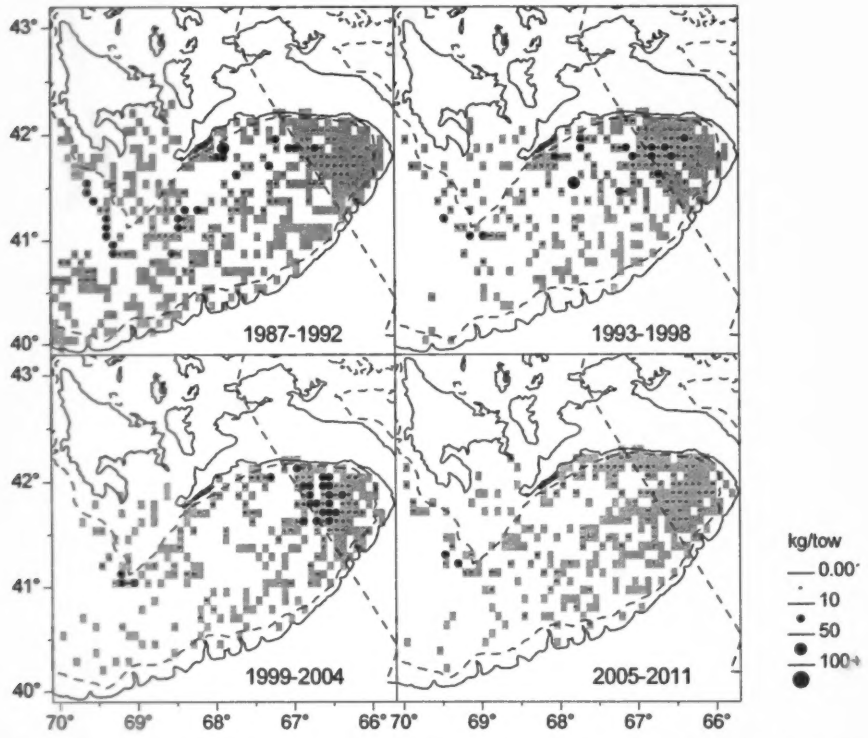


Figure 34. Distribution of winter flounder catches (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

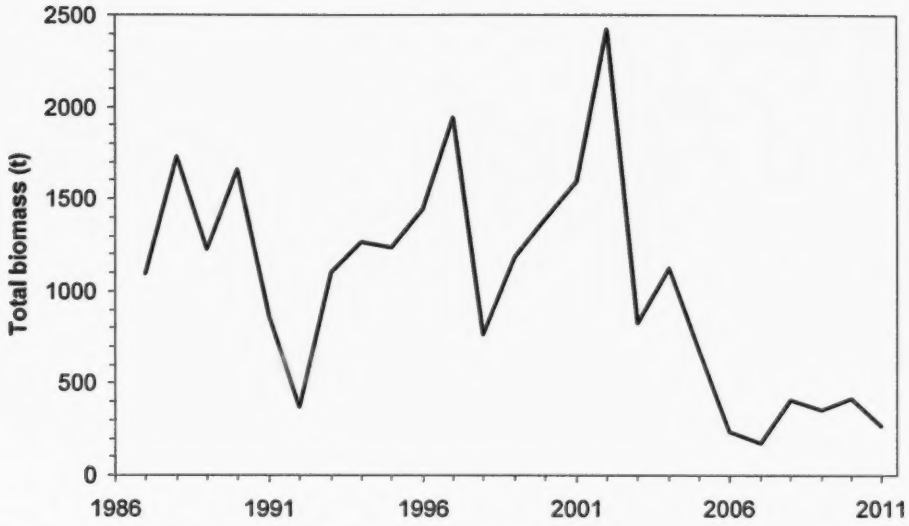


Figure 35. Total biomass estimates of winter flounder from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

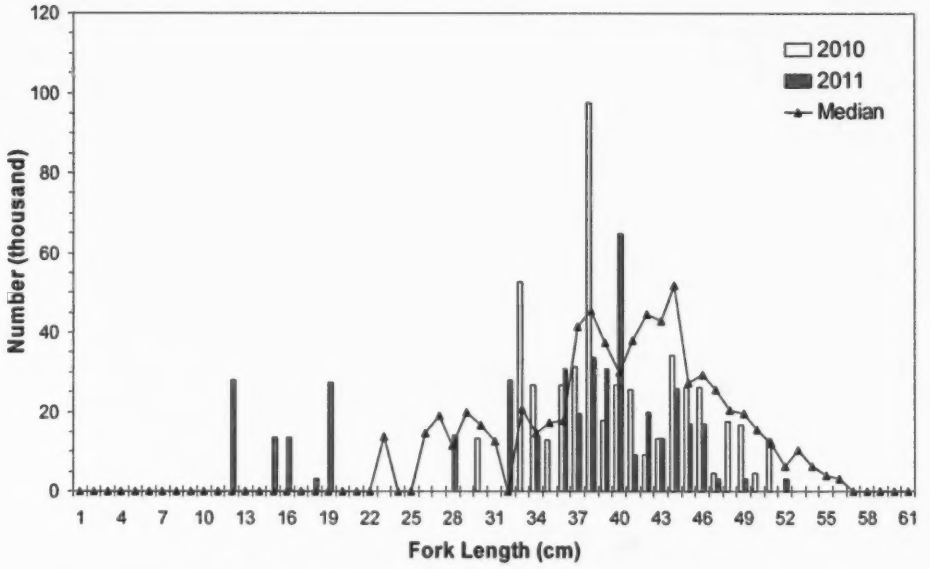


Figure 36. Length stratified total number (thousands) for winter flounder from Georges Bank Survey strata 5Z1-5Z4 for 2010 and 2011 compared to the median for 1987-2009.

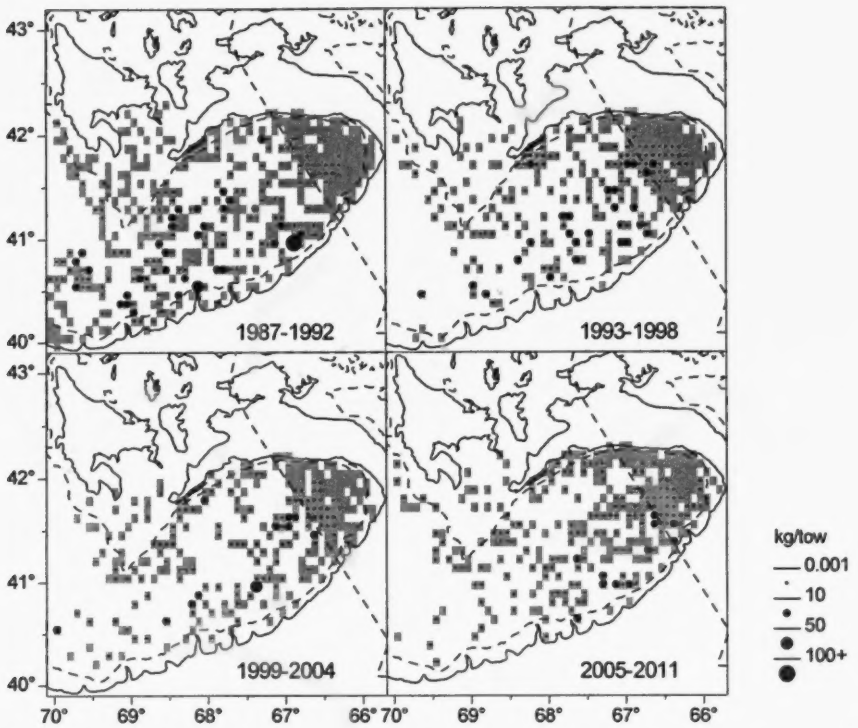


Figure 37. Distribution of brill/windowpane flounder catches (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

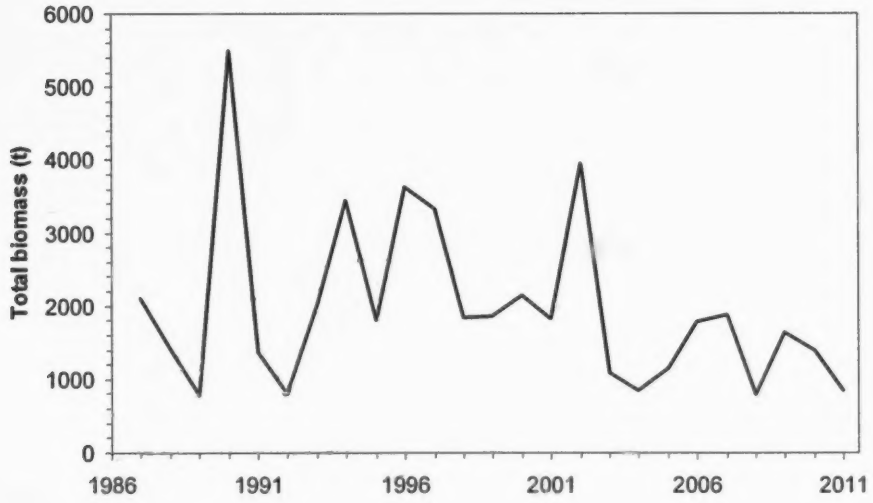


Figure 38. Total biomass estimates of brill/windowpane flounder from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

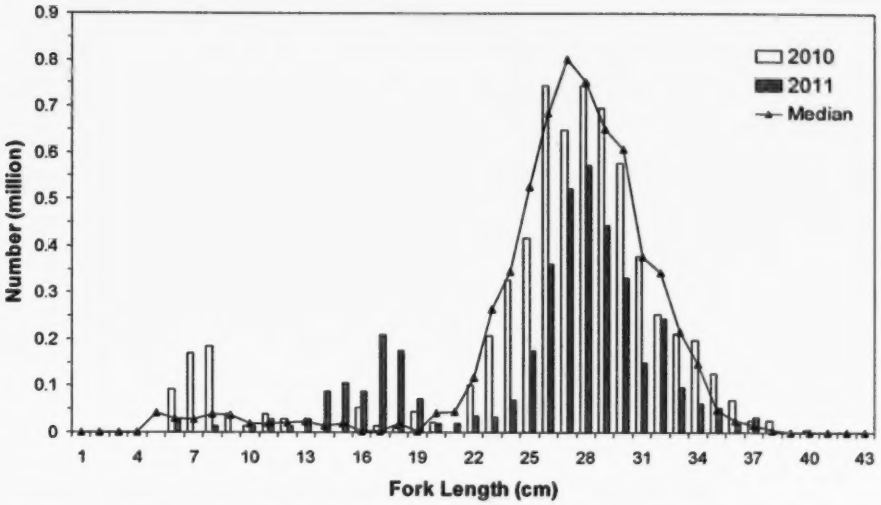


Figure 39. Length stratified total number (millions) for brill/windowpane flounder from Georges Bank Survey strata 5Z1-5Z4 for 2010 and 2011 compared to the median for 1987-2009.

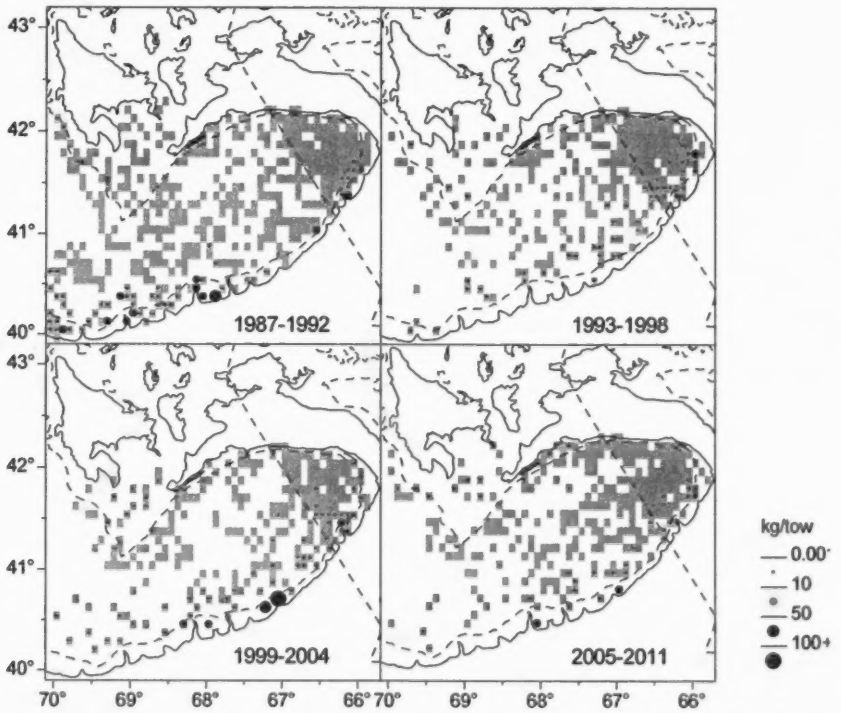


Figure 40. Distribution of four-spot flounder catches (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

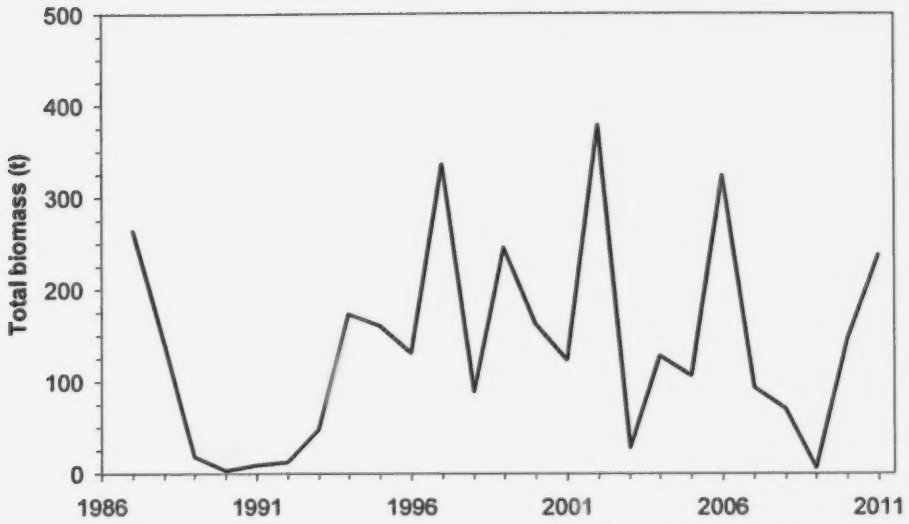


Figure 41. Total biomass estimates of four-spot flounder from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

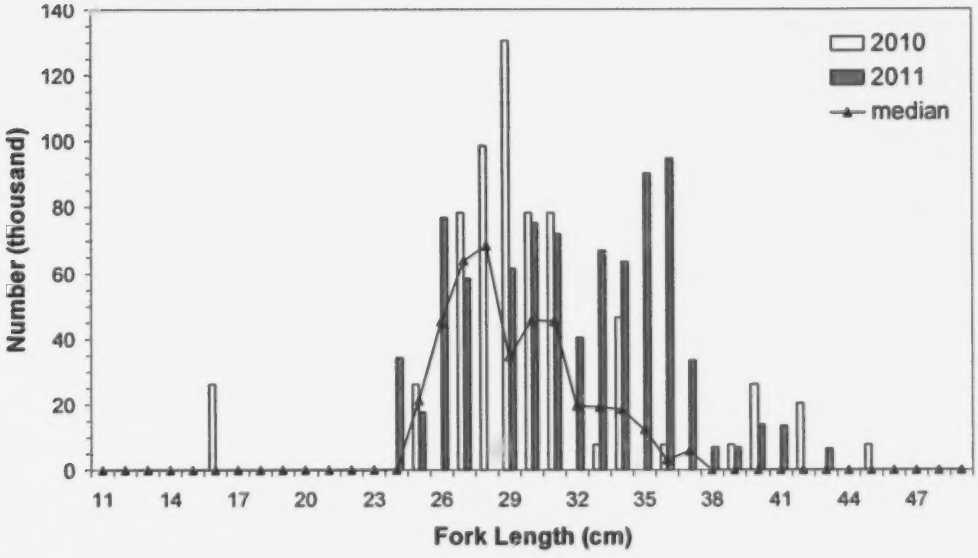


Figure 42. Length stratified total number (thousands) for four-spot flounder from Georges Bank Survey strata 5Z1-5Z4 for 2010 and 2011 compared to the median for 1987-2009.

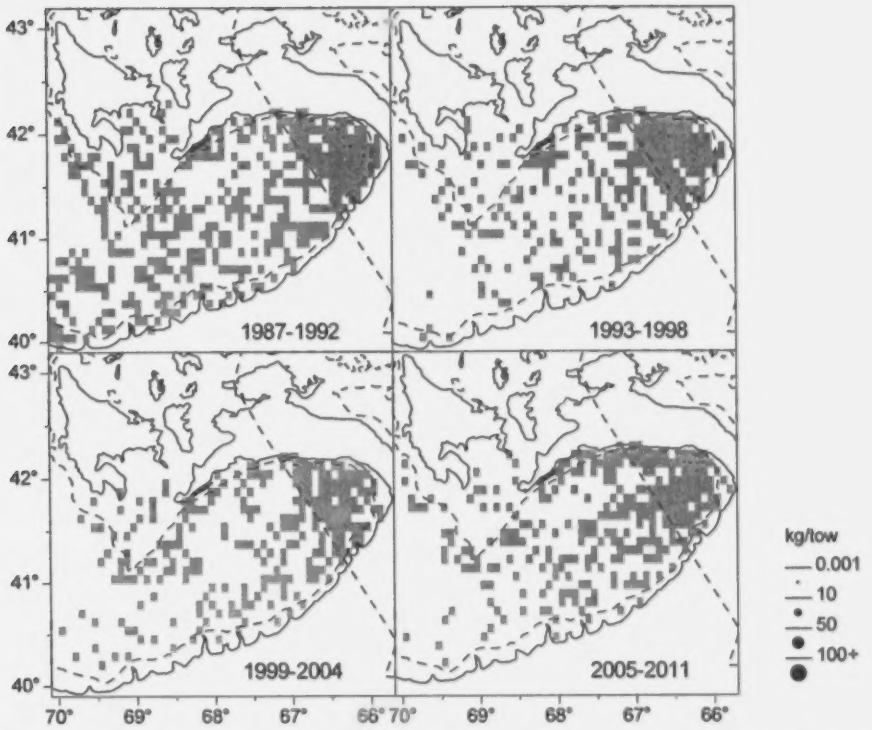


Figure 43. Distribution of Atlantic halibut catches (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

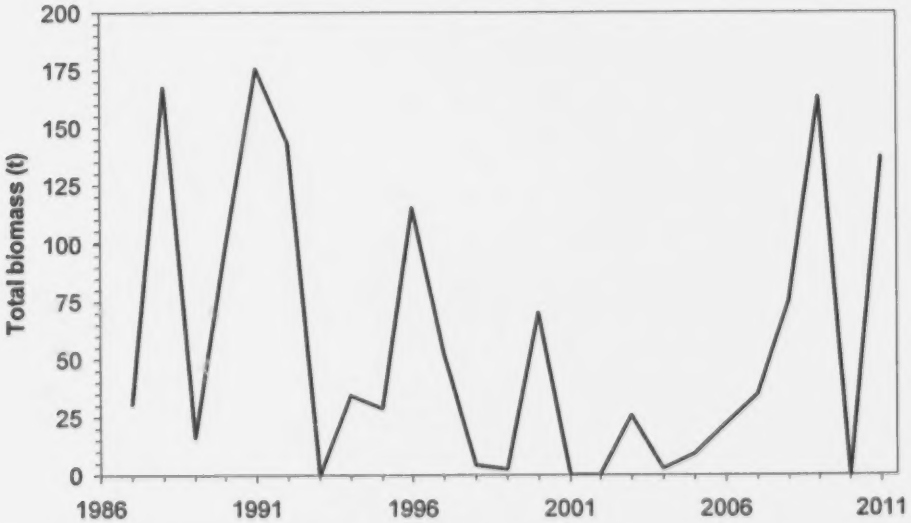


Figure 44. Total biomass estimates of Atlantic halibut from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

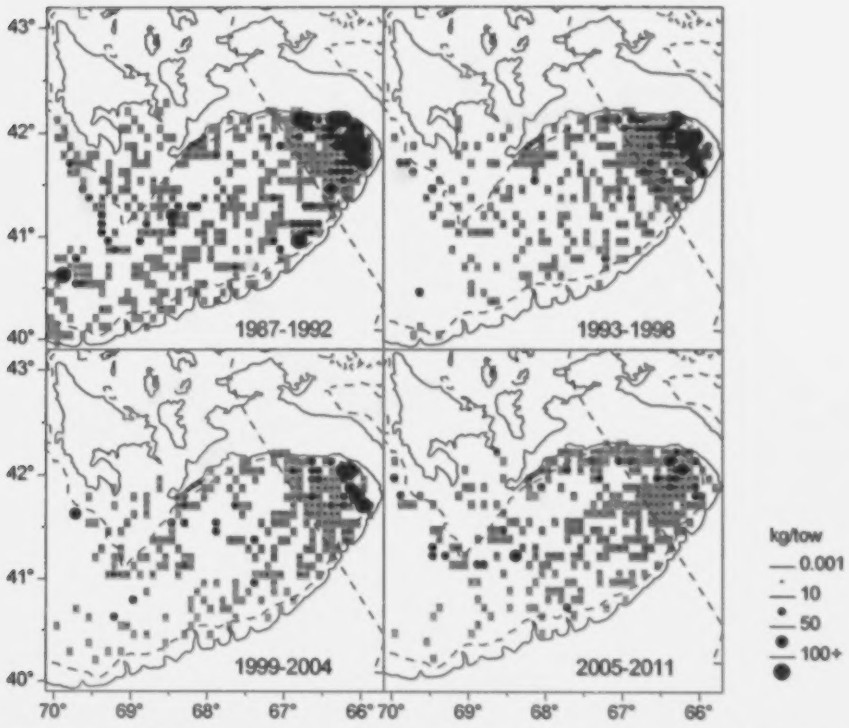


Figure 45. Distribution of longhorn sculpin catches (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

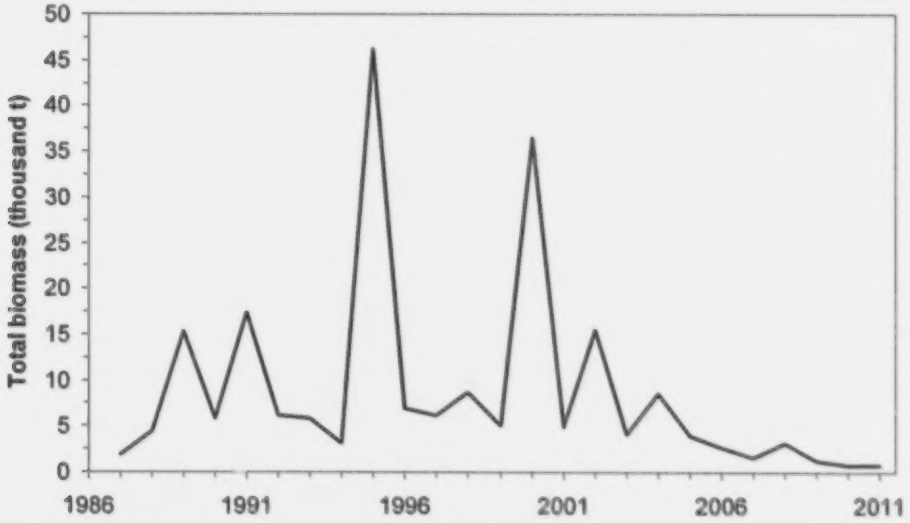


Figure 46. Total biomass estimates of longhorn sculpin from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

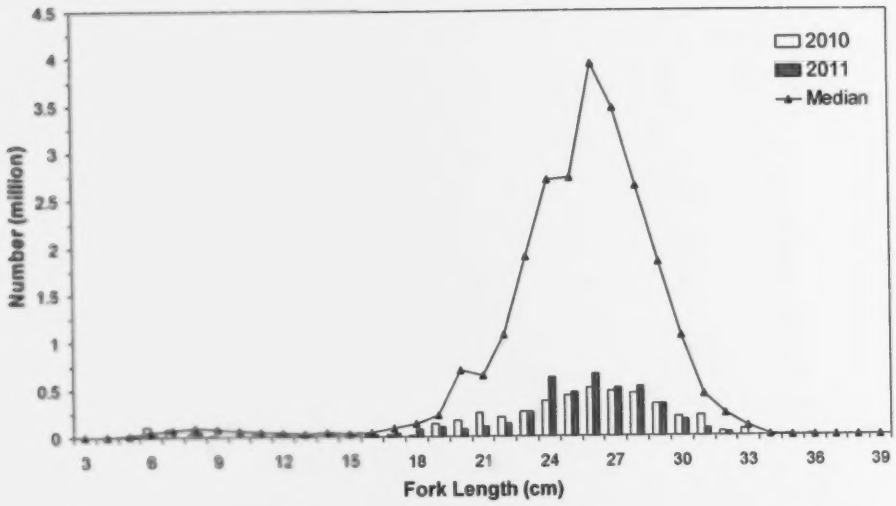


Figure 47. Length stratified total number (millions) for longhorn sculpin from Georges Bank Survey strata 5Z1-5Z4 for 2010 and 2011 compared to the median for 1987-2009.

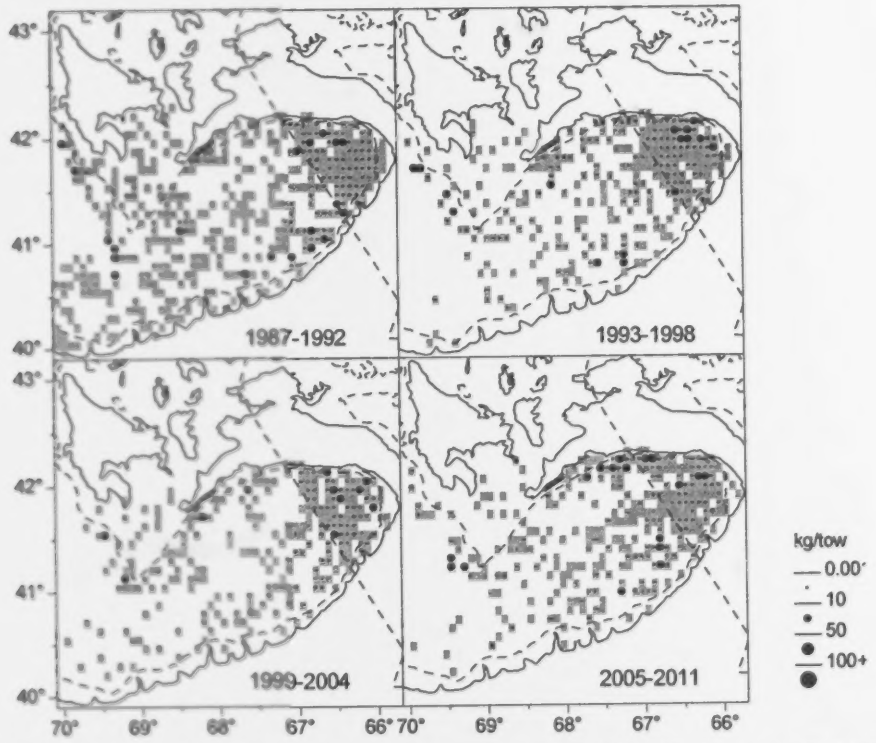


Figure 48. Distribution of sea raven (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

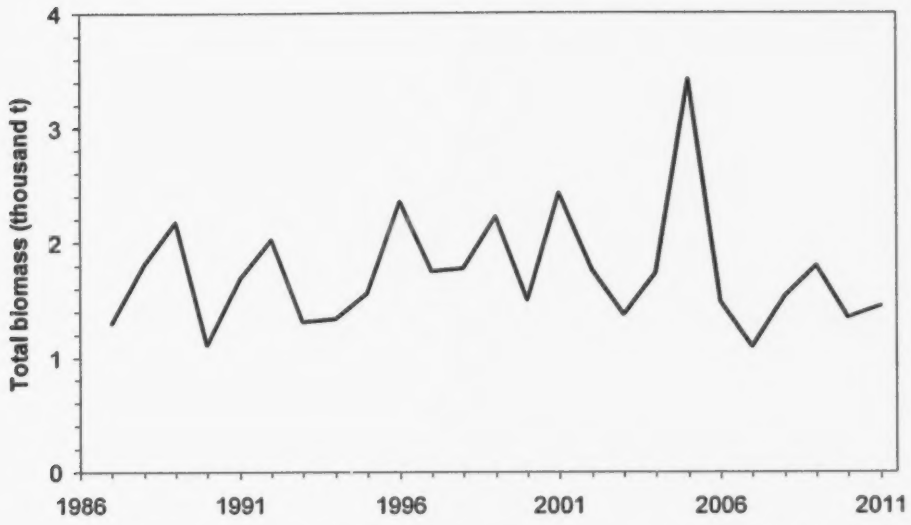


Figure 49. Total biomass estimates of sea raven from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

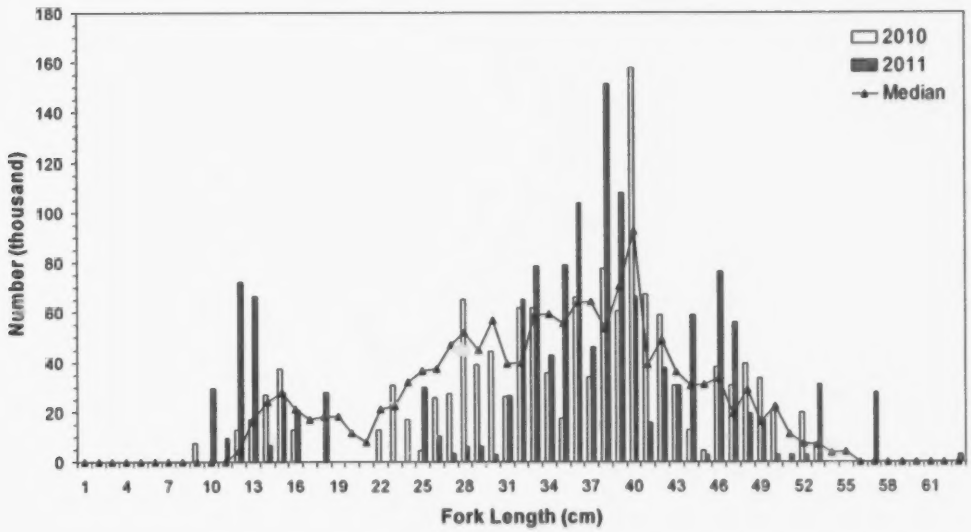


Figure 50. Length stratified total number (thousands) for sea raven from Georges Bank Survey strata 5Z1-5Z4 for 2010 and 2011 compared to the median for 1987-2009.

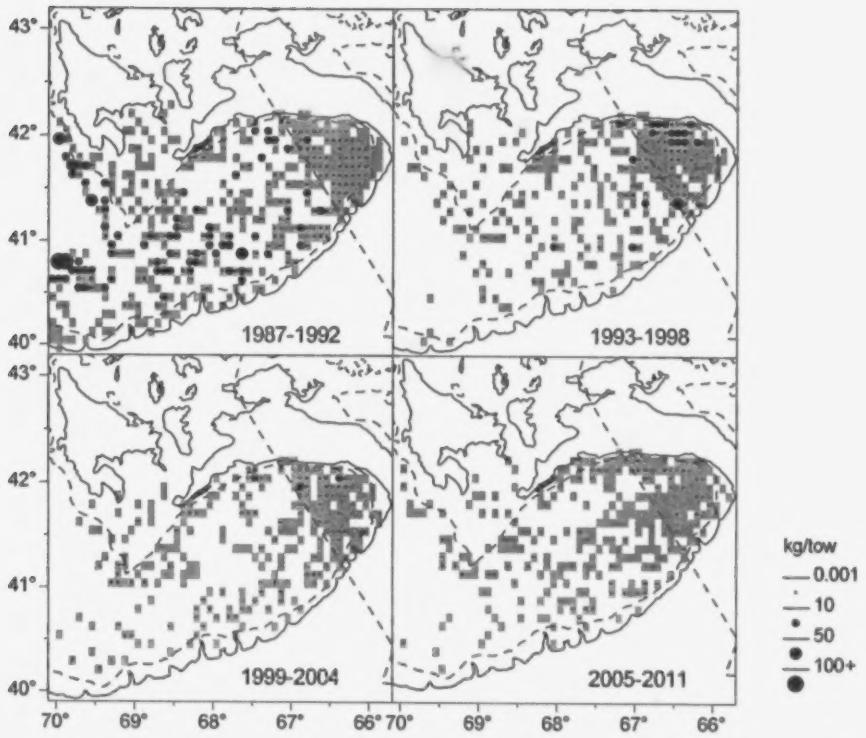


Figure 51. Distribution of ocean pout (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

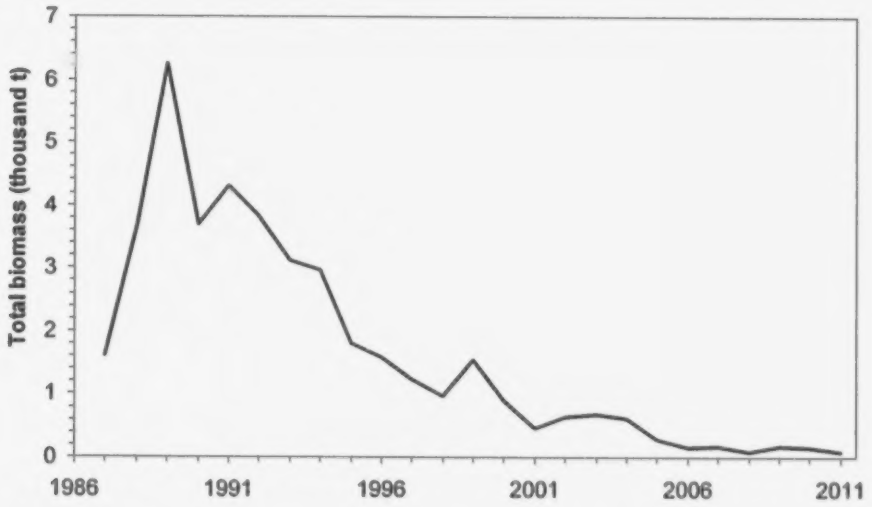


Figure 52. Total biomass estimates of ocean pout from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

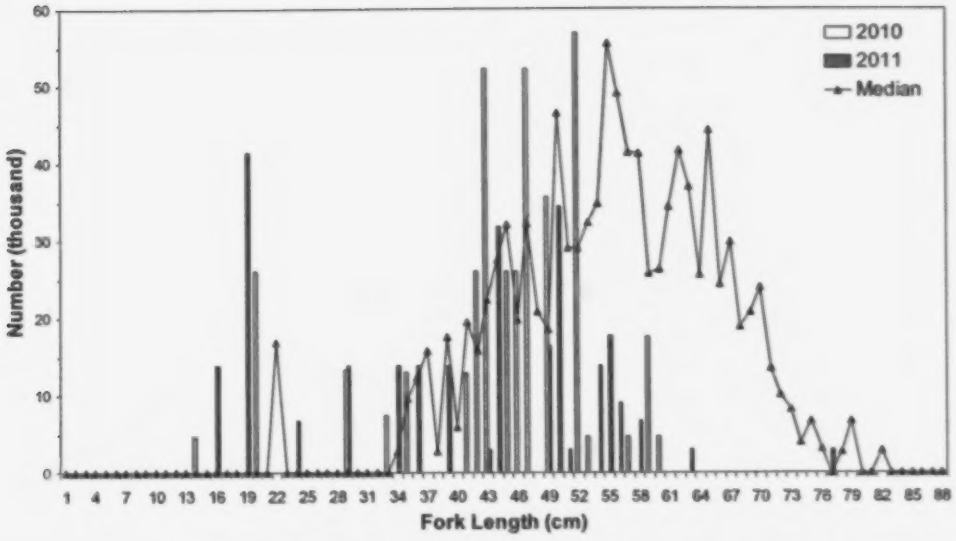


Figure 53. Length stratified total number (thousands) for ocean pout from Georges Bank Survey strata 5Z1-5Z4 for 2010 and 2011 compared to the median for 1987-2009.

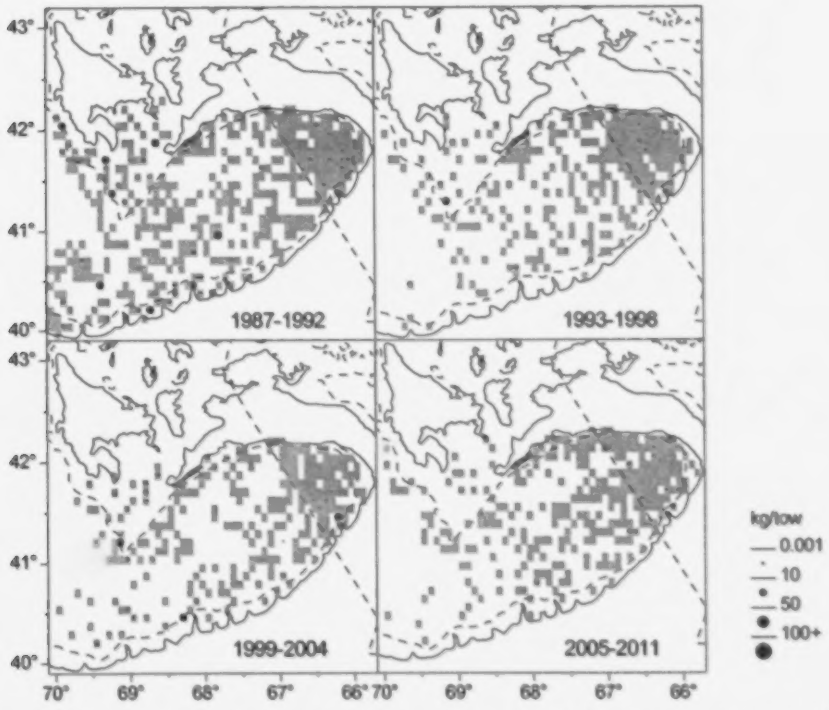


Figure 54. Distribution of monkfish (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

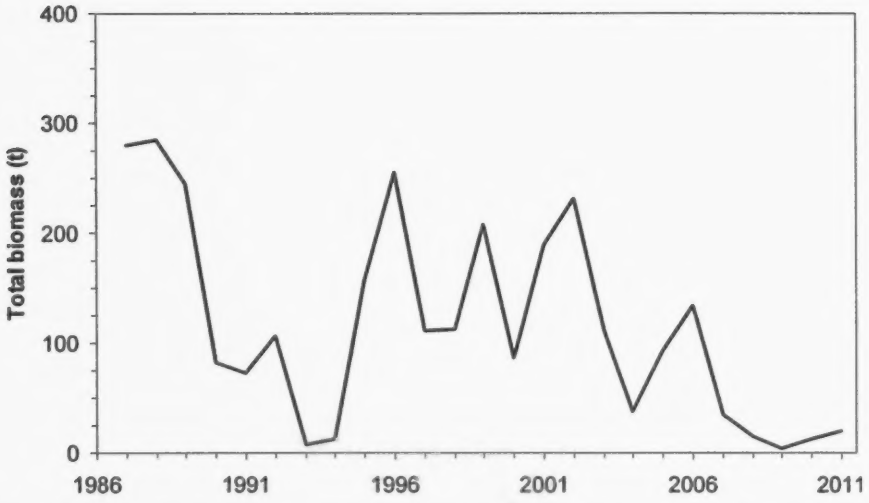


Figure 55. Total biomass estimates of monkfish from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

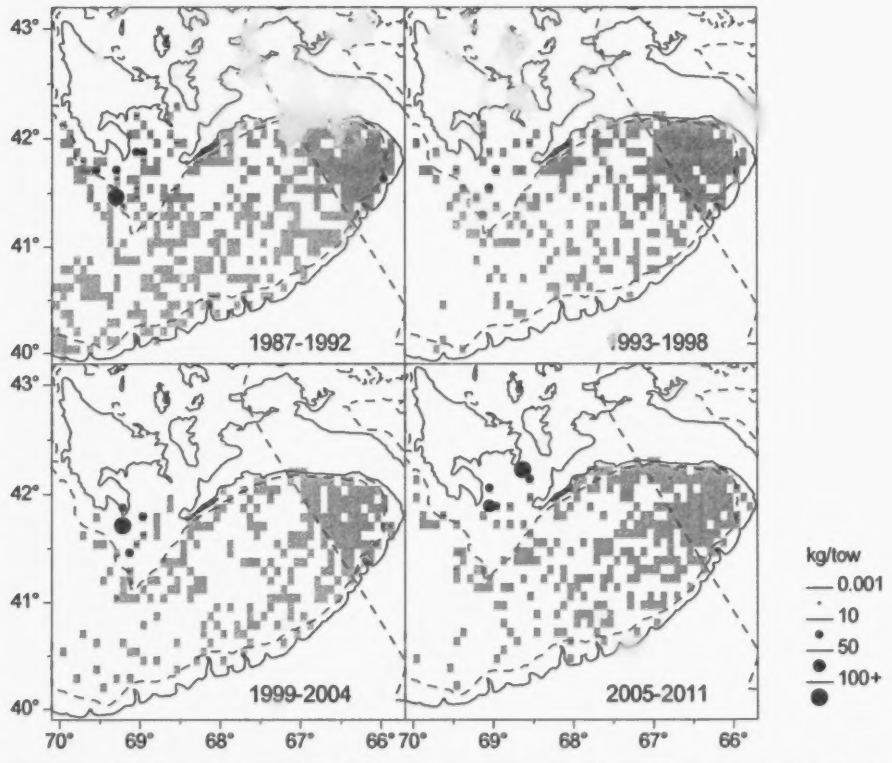


Figure 56. Distribution of redfish (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

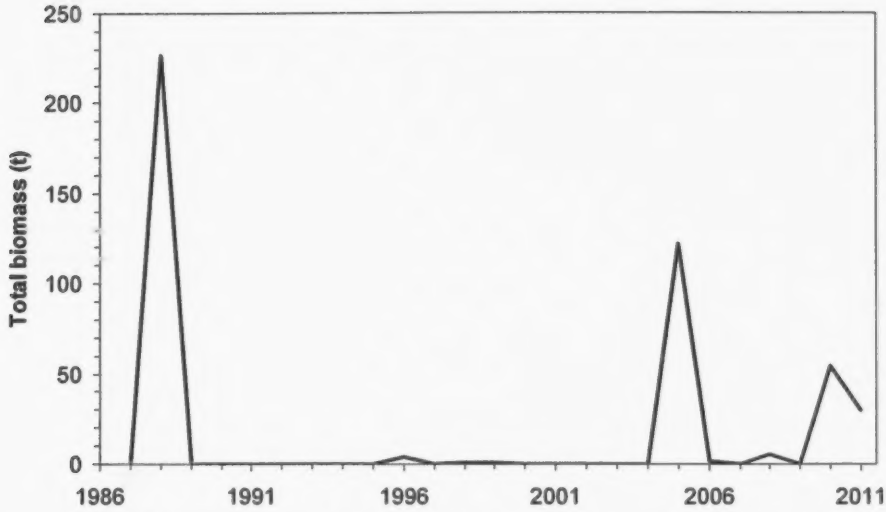


Figure 57. Total biomass estimates of redfish from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

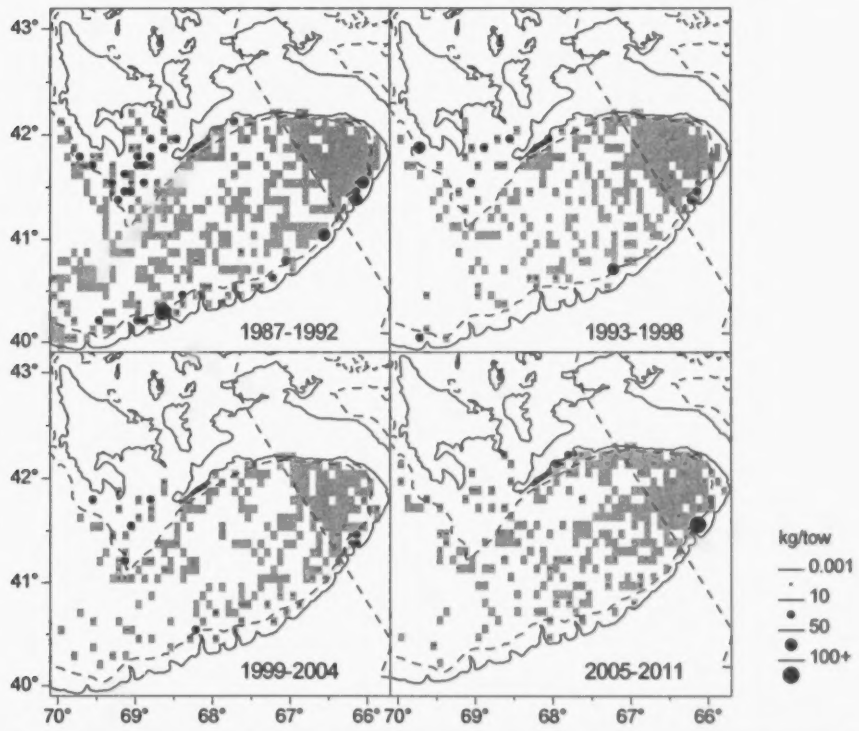


Figure 58. Distribution of red hake (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

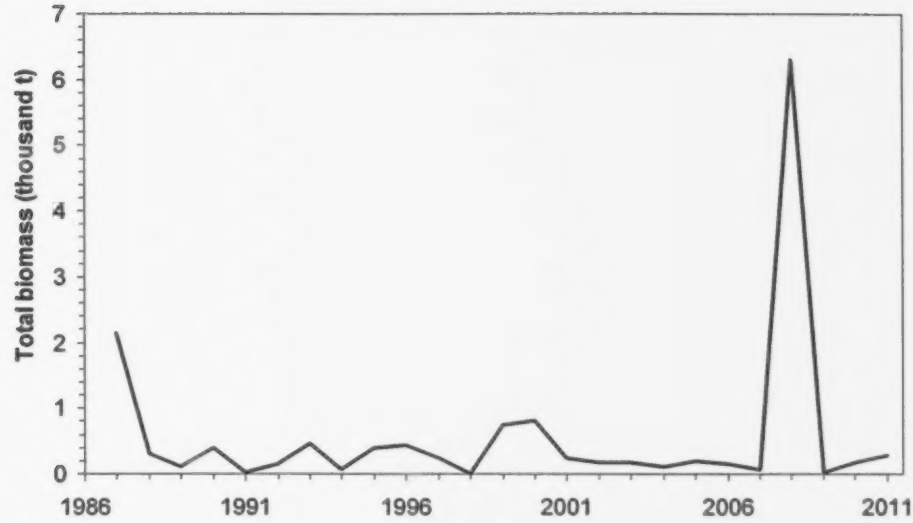


Figure 59. Total biomass estimates of red hake from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

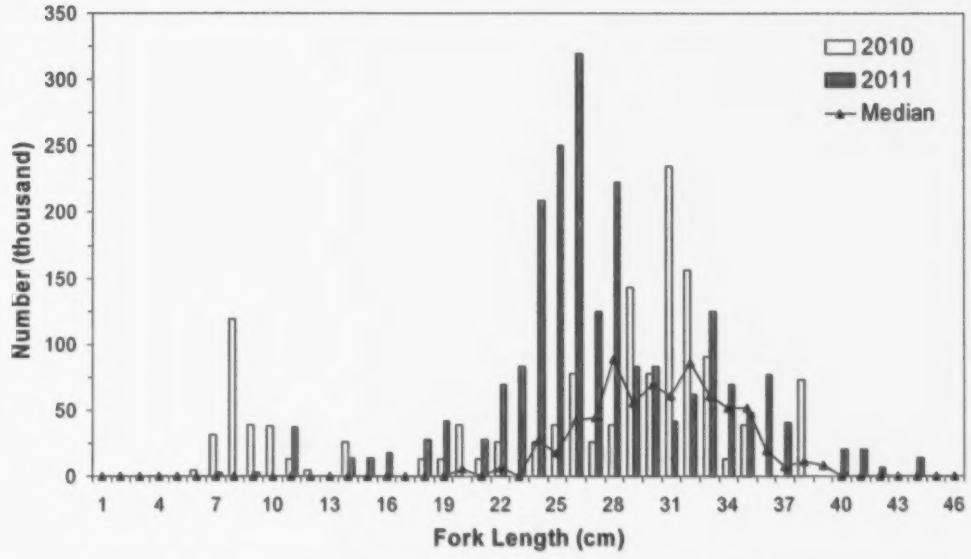


Figure 60. Length stratified total number (thousands) for red hake from Georges Bank Survey strata 5Z1-5Z4 for 2010 and 2011 compared to the median for 1987-2009.

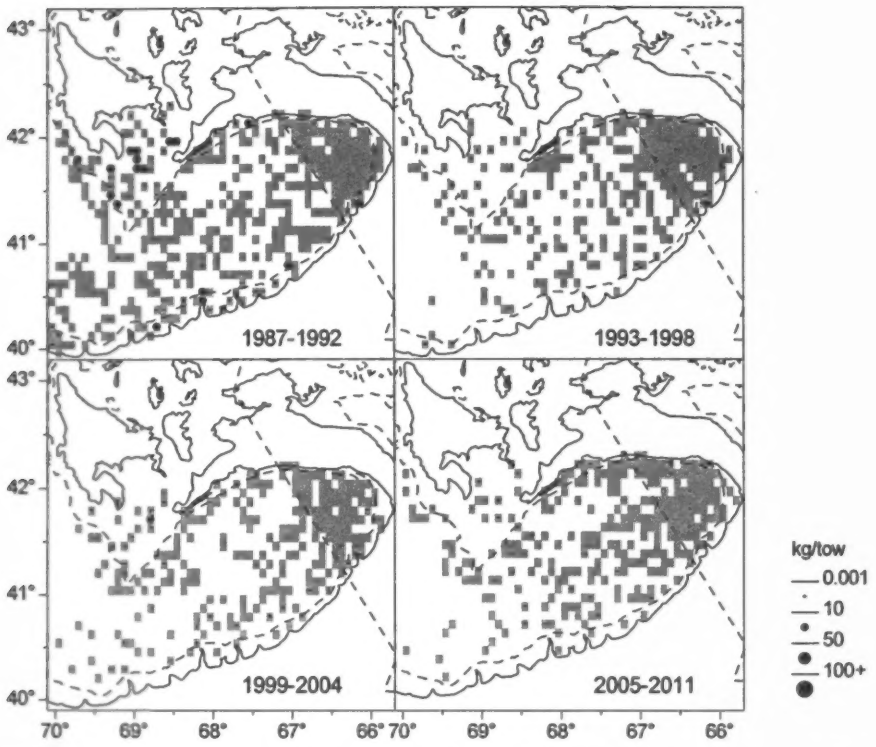


Figure 61. Distribution of white hake (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

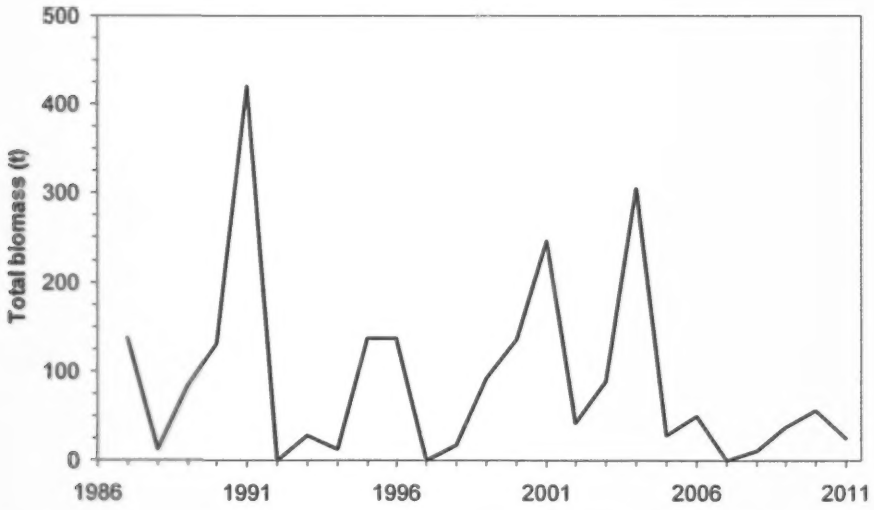


Figure 62. Total biomass estimates of white hake from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

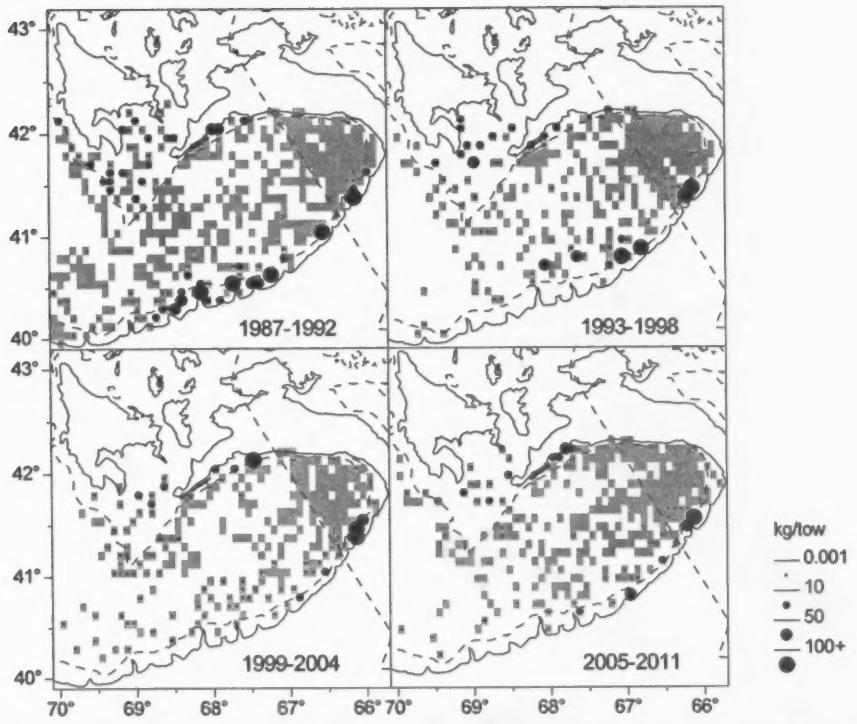


Figure 63. Distribution of silver hake (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

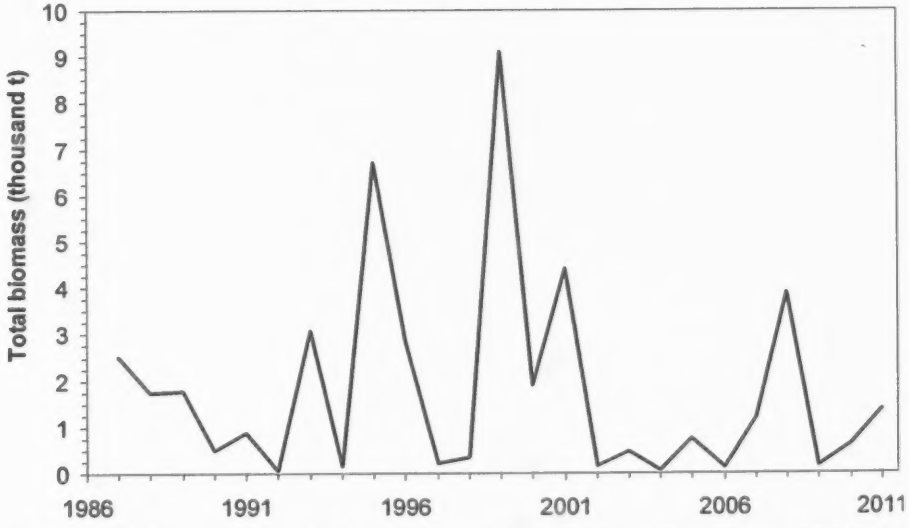


Figure 64. Total biomass estimates of silver hake from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

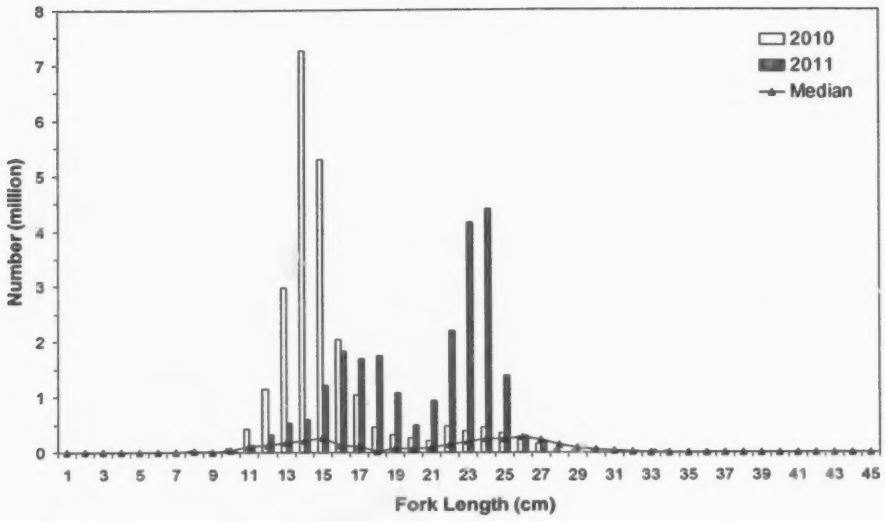


Figure 65. Length stratified total number (millions) for silver hake from Georges Bank Survey strata 5Z1-5Z4 for 2010 and 2011 compared to the median for 1987-2009.

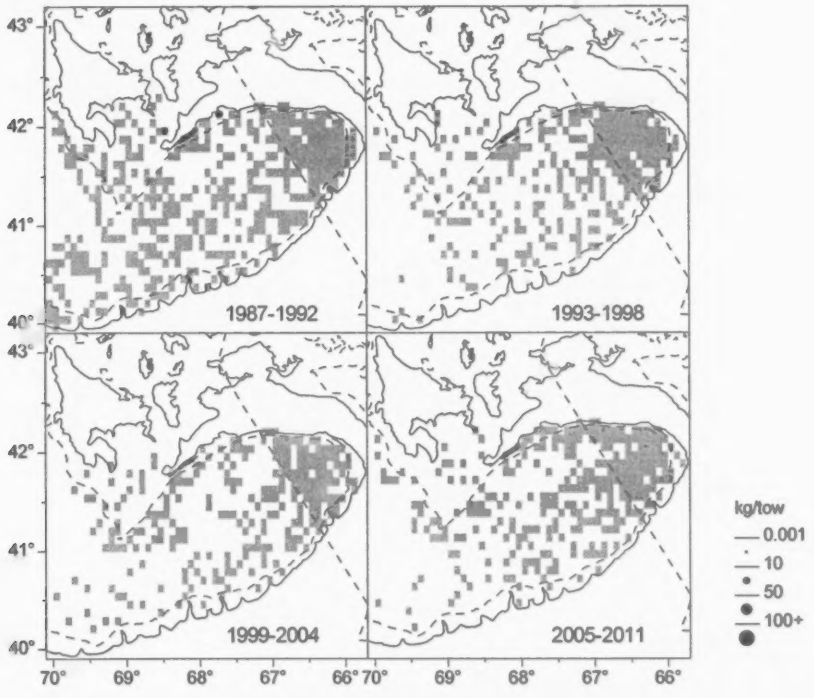


Figure 66. Distribution of cusk (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

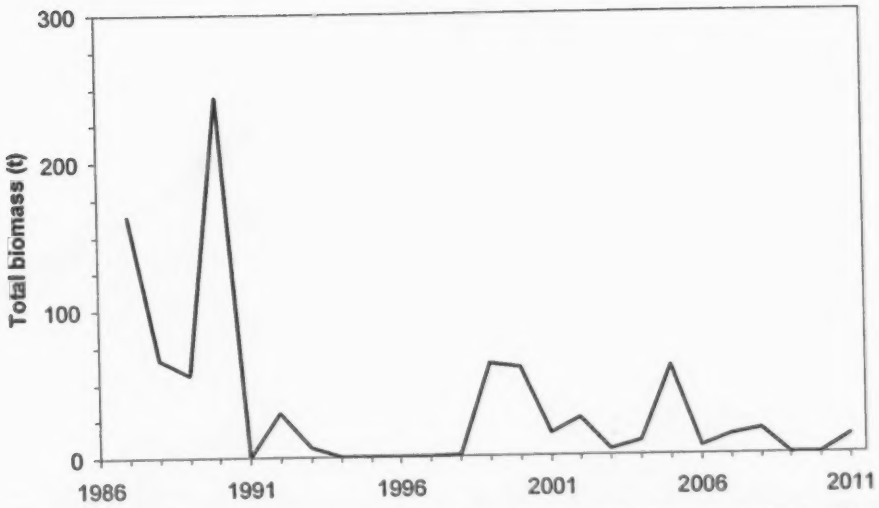


Figure 67. Total biomass estimates of cusk from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

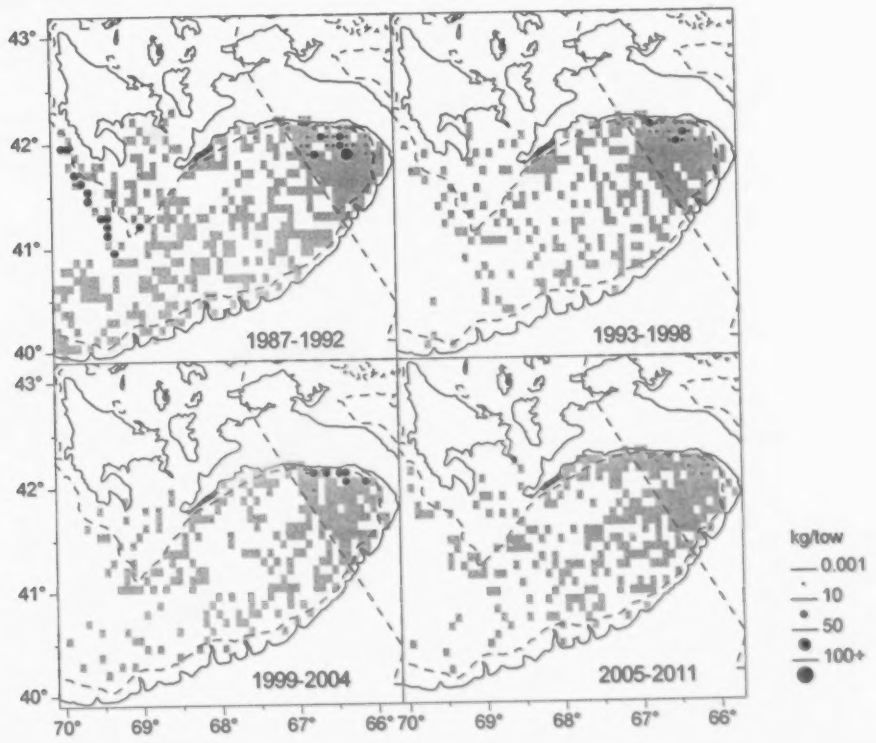


Figure 68. Distribution of Atlantic wolffish (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

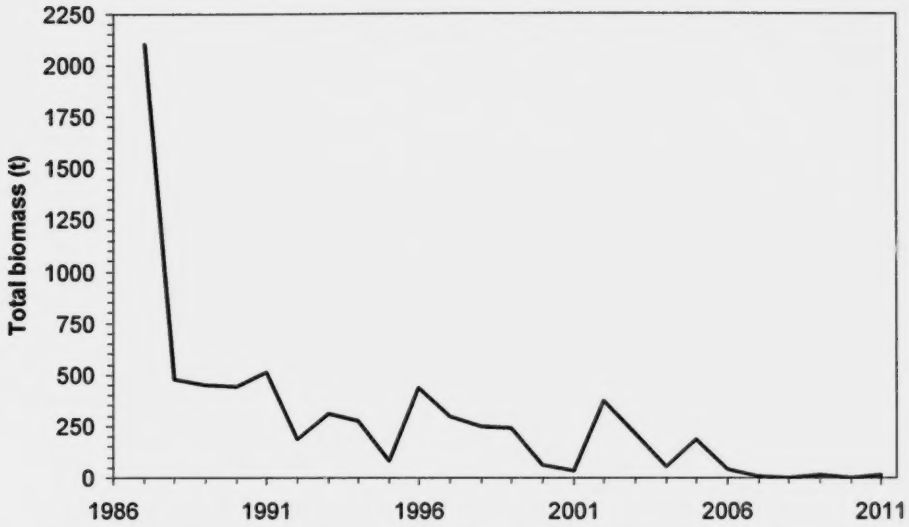


Figure 69. Total biomass estimates of Atlantic wolffish from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

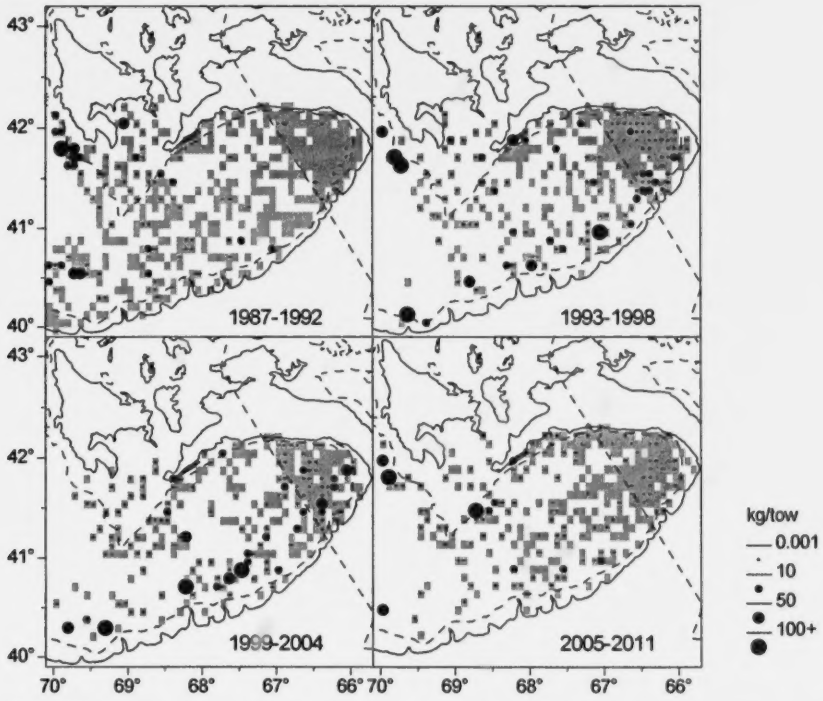


Figure 70. Distribution of Atlantic herring (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

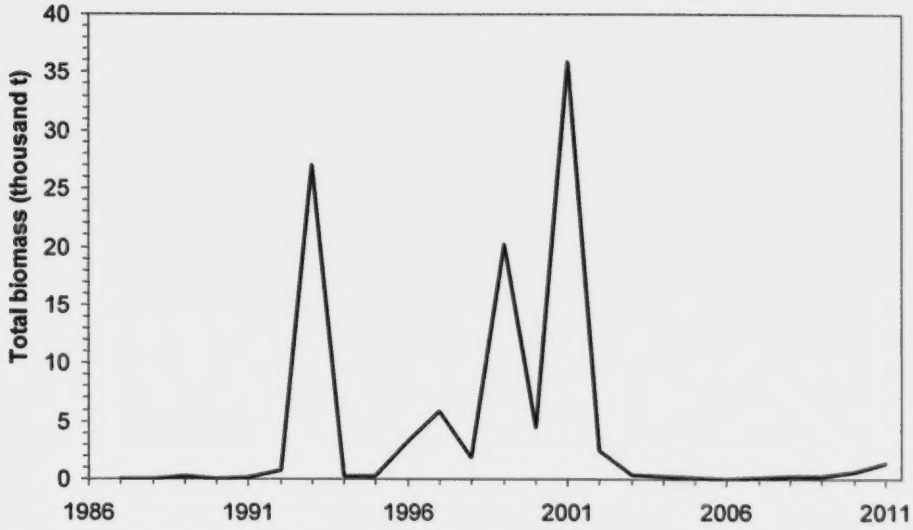


Figure 71. Total biomass estimates of Atlantic herring from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

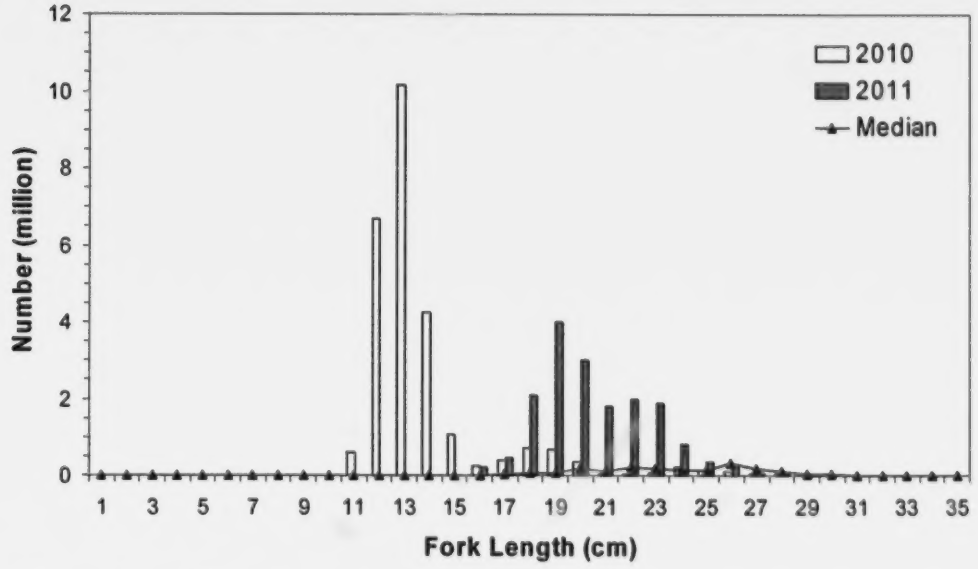


Figure 72. Length stratified total number (millions) for Atlantic herring from Georges Bank Survey strata 5Z1-5Z4 for 2010 and 2011 compared to the median for 1987-2009.

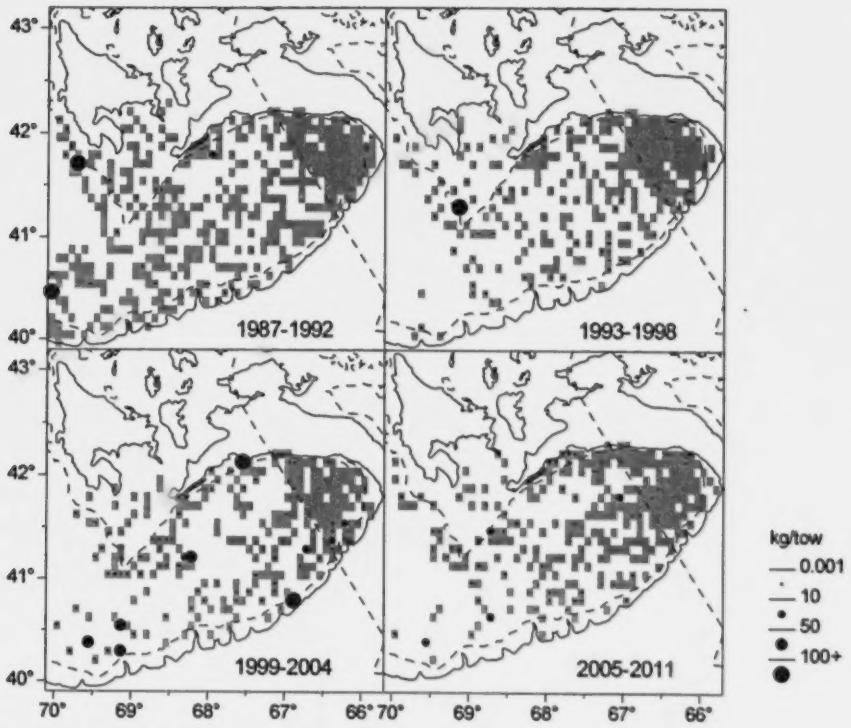


Figure 73. Distribution of Atlantic mackerel (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

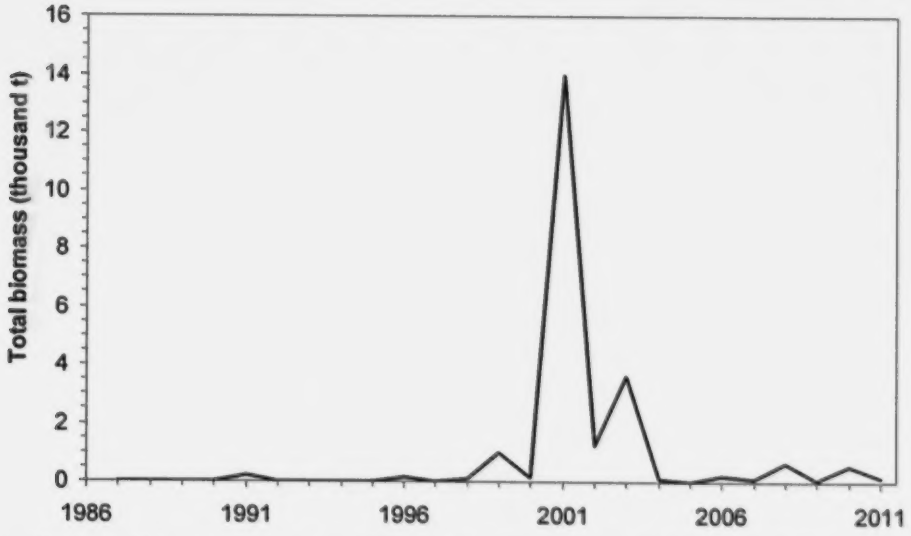


Figure 74. Total biomass estimates of Atlantic mackerel from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

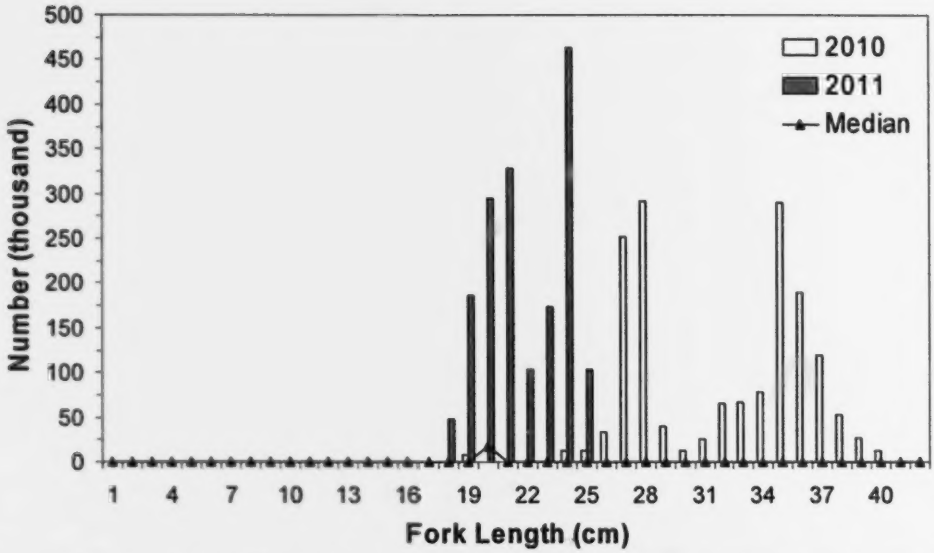


Figure 75. Length stratified total number (thousands) for Atlantic mackerel from Georges Bank Survey strata 5Z1-5Z4 for 2010 and 2011 compared to the median for 1987-2009.

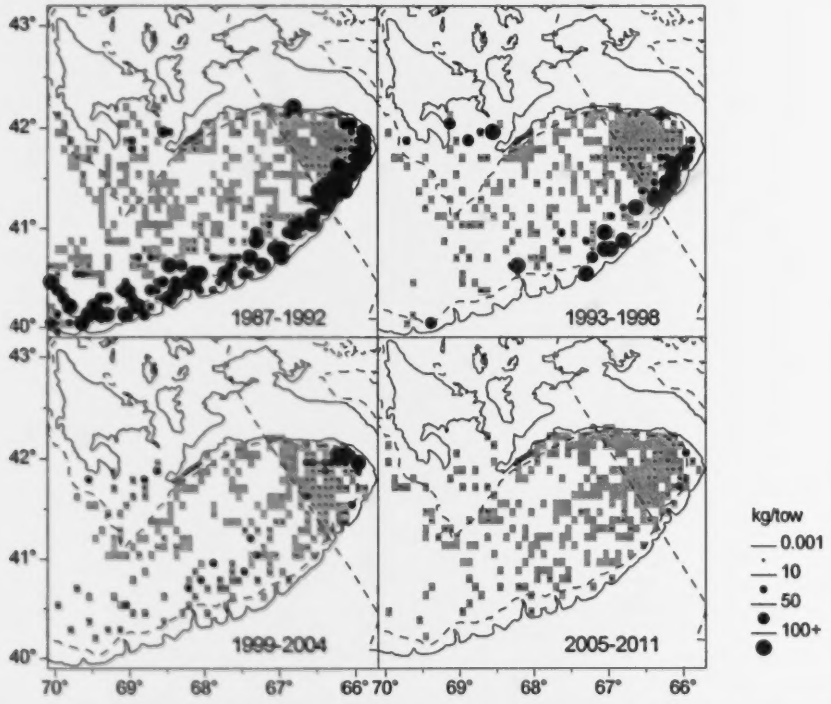


Figure 76. Distribution of spiny dogfish (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

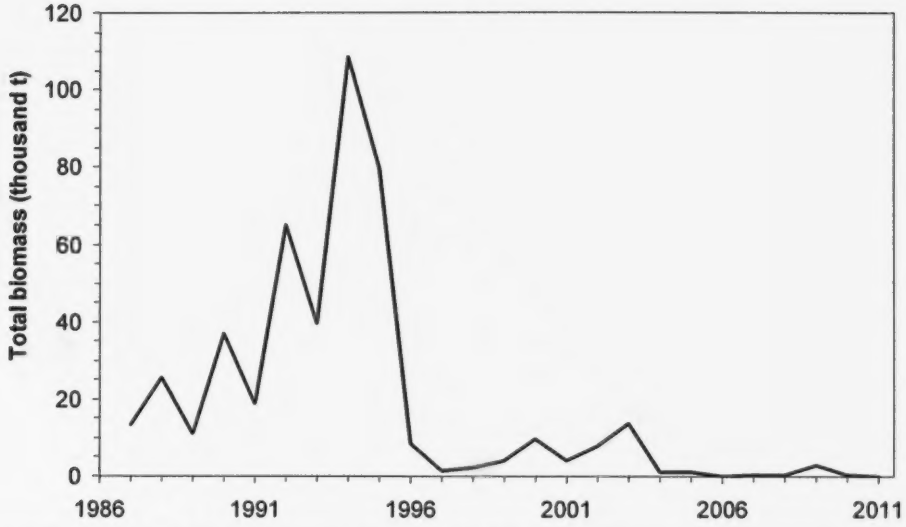


Figure 77. Total biomass estimates of spiny dogfish from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

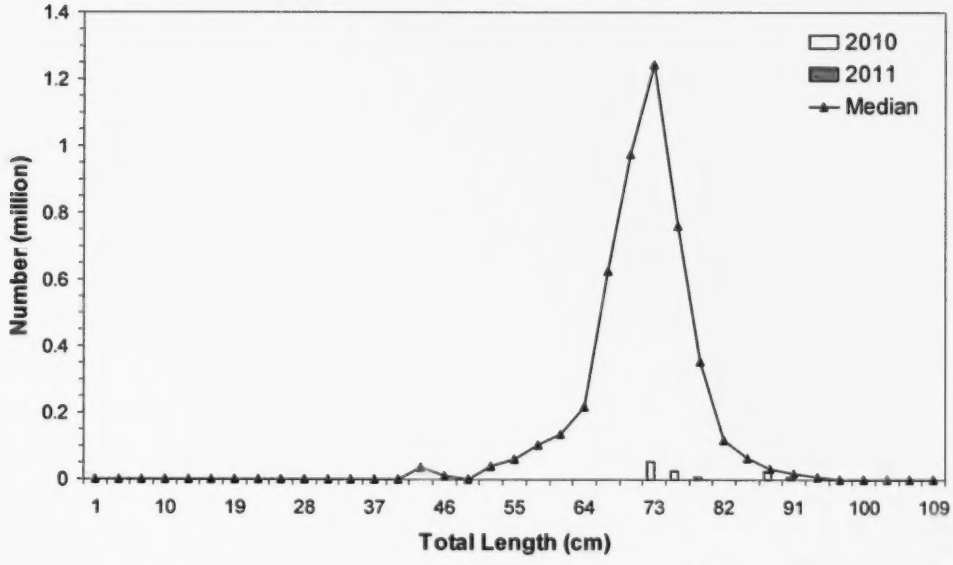


Figure 78. Length stratified total number (millions) for spiny dogfish from Georges Bank Survey strata 5Z1-5Z4 for 2010 and 2011 compared to the median for 1987-2009.

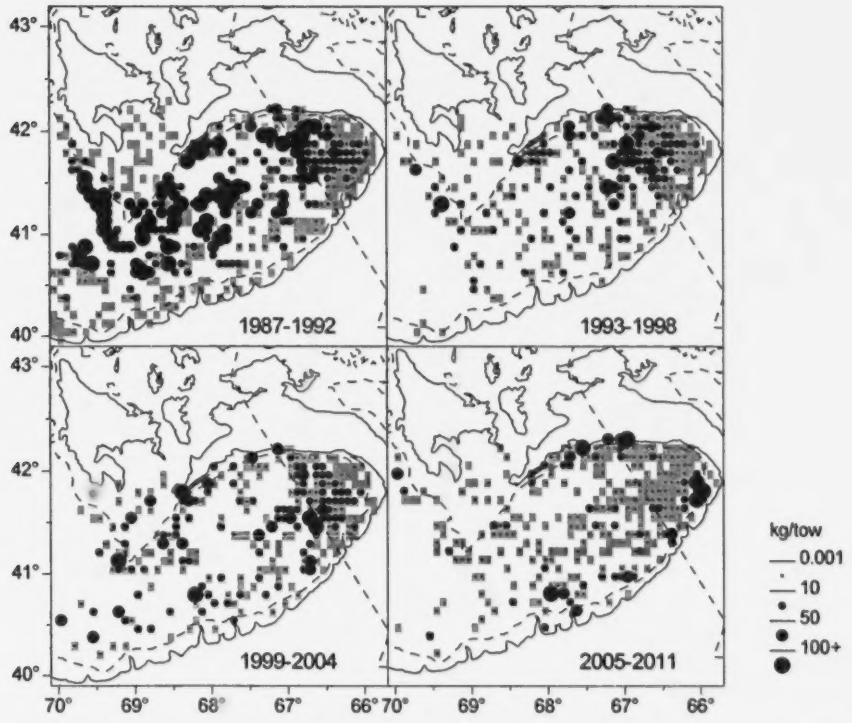


Figure 79. Distribution of winter skate (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

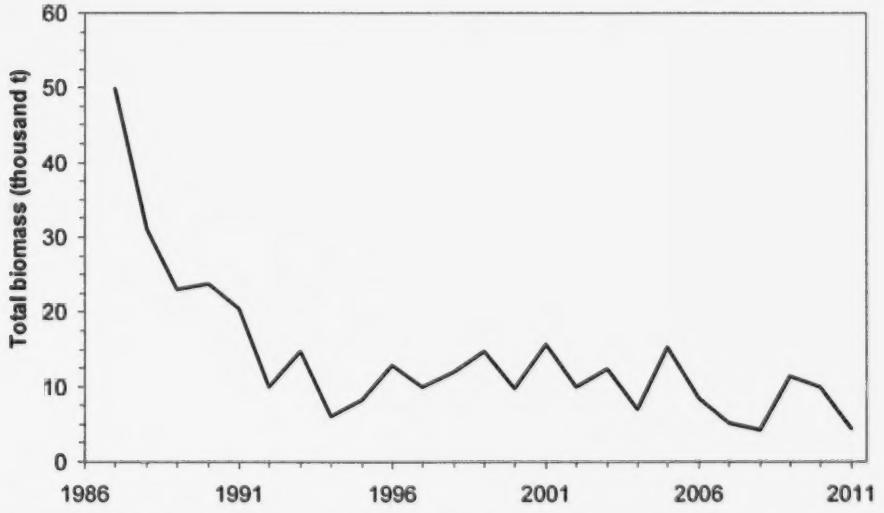


Figure 80. Total biomass estimates of winter skate from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

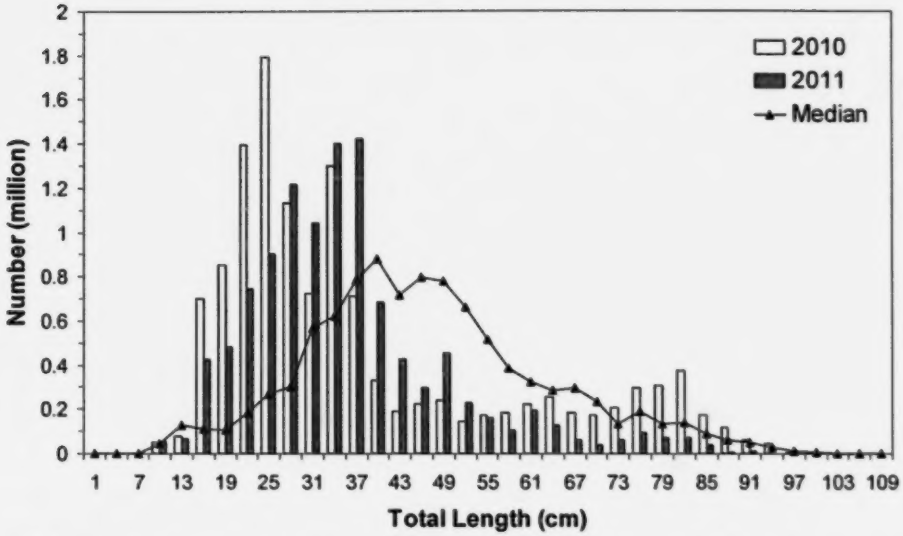


Figure 81. Length stratified total number (millions) for winter skate from Georges Bank Survey strata 5Z1-5Z4 for 2010 and 2011 compared to the median for 1987-2009.

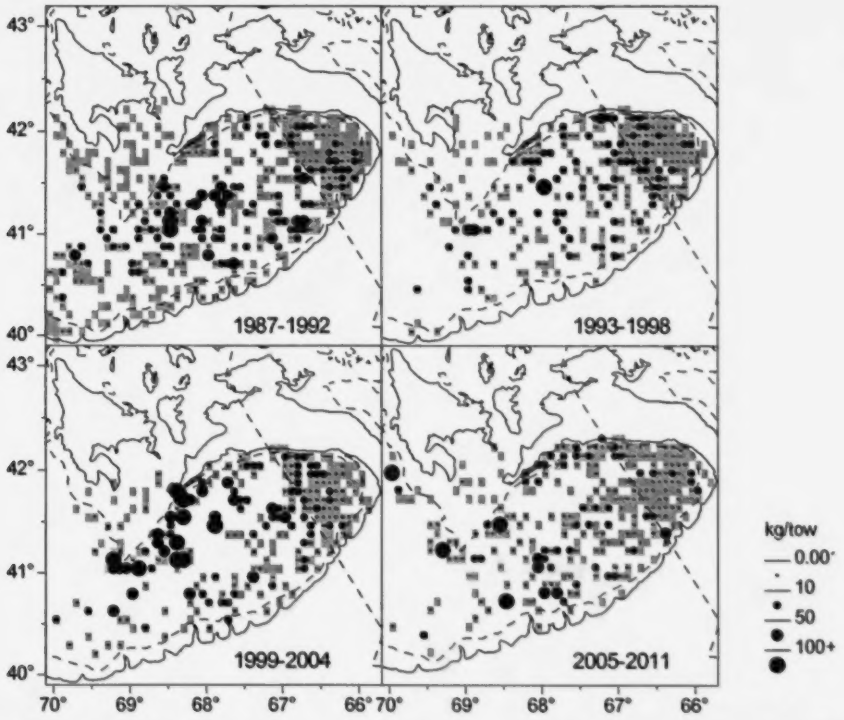


Figure 82. Distribution of little skate (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

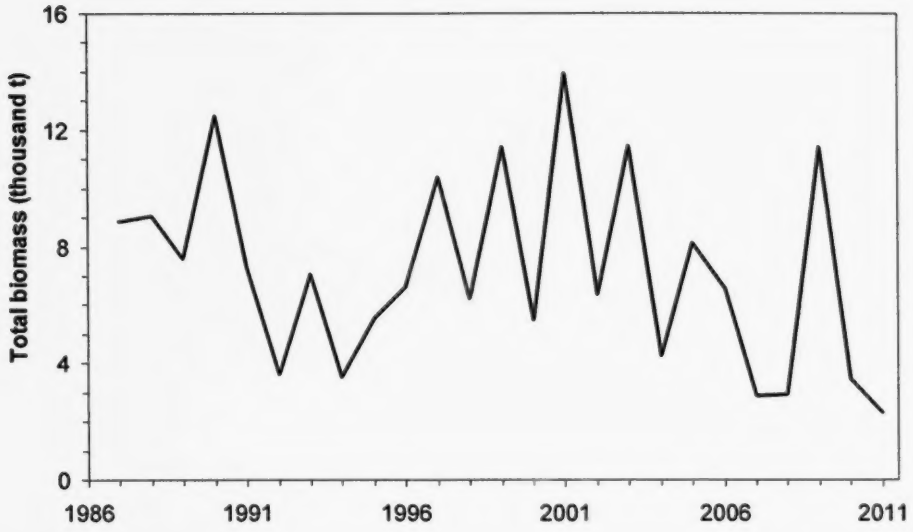


Figure 83. Total biomass estimates of little skate from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

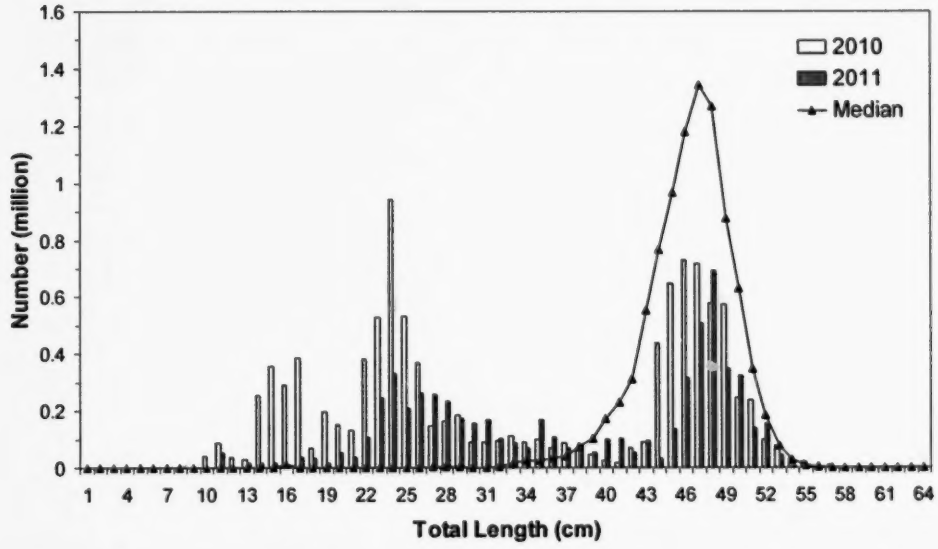


Figure 84. Length stratified total number (millions) for little skate from Georges Bank Survey strata 5Z1-5Z4 for 2010 and 2011 compared to the median for 1987-2009.

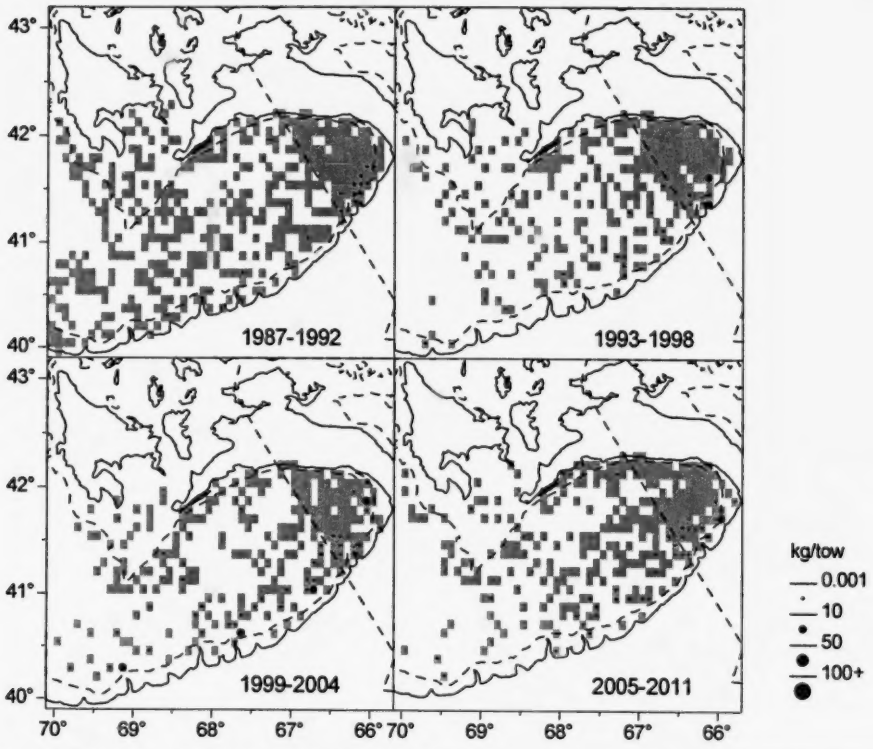


Figure 85. Distribution of barndoor skate (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

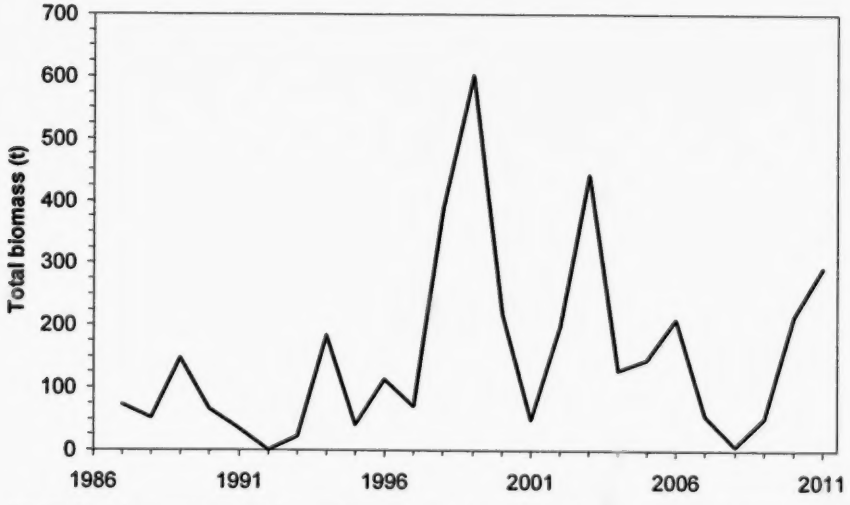


Figure 86. Total biomass estimates of barndoor skate from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

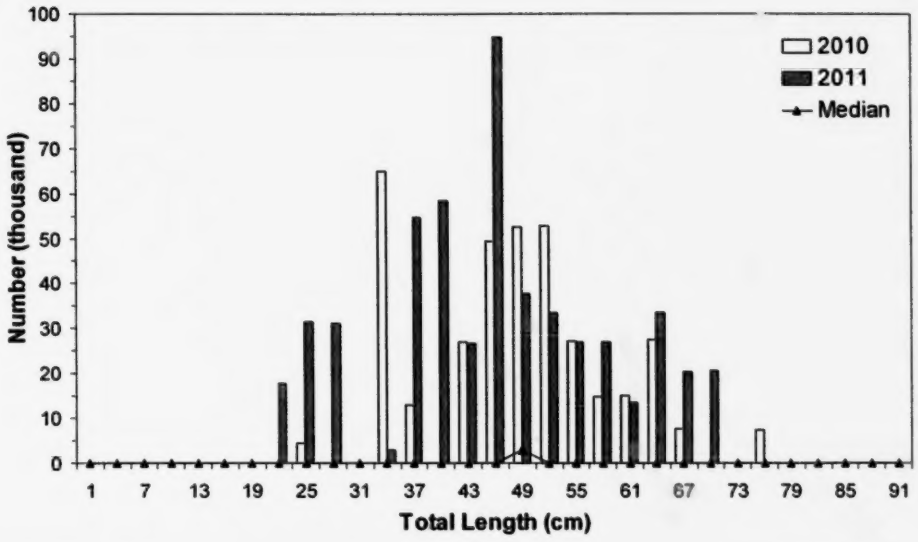


Figure 87. Length stratified total number (thousands) for barndoor skate from Georges Bank Survey strata 5Z1-5Z4 for 2010 and 2011 compared to the median for 1987-2009.

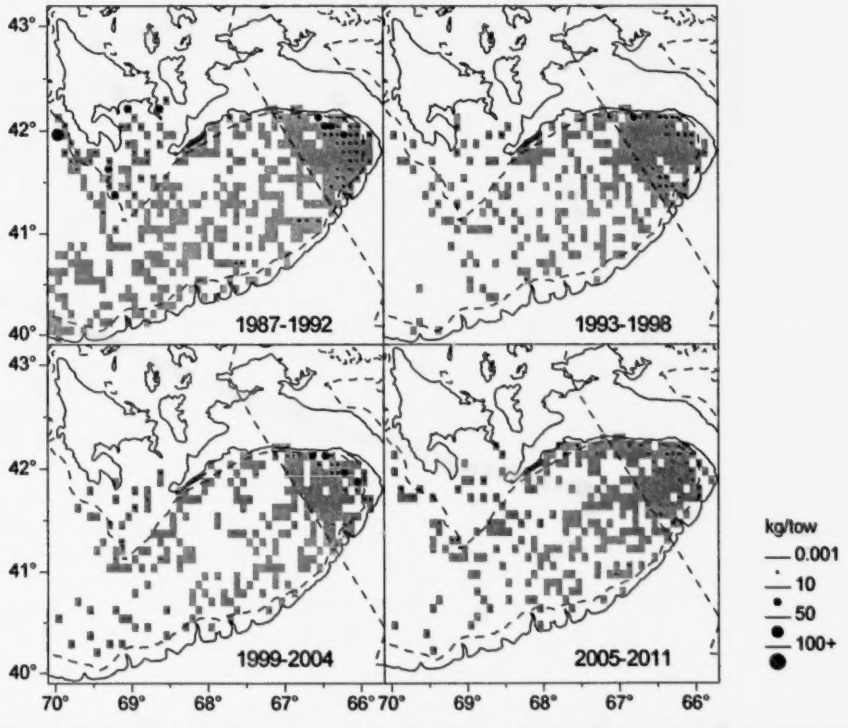


Figure 88. Distribution of thorny skate (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

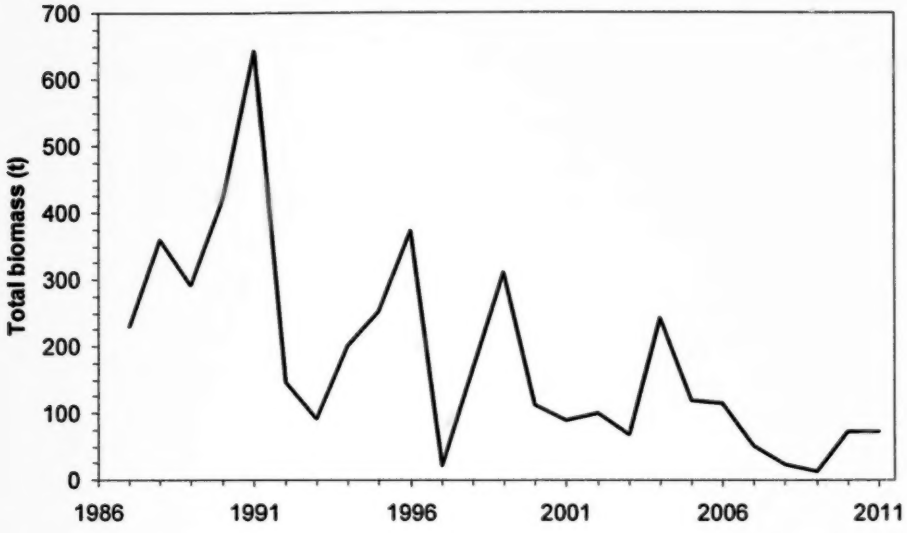


Figure 89. Total biomass estimates of thorny skate from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

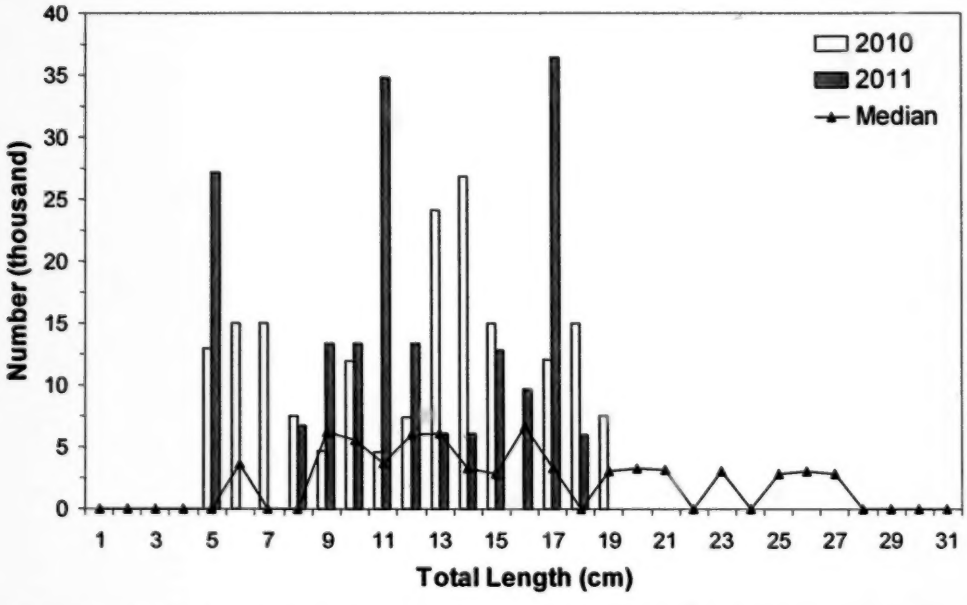


Figure 90. Length stratified total number (thousands) for thorny skate from Georges Bank Survey strata 5Z1-5Z4 for 2010 and 2011 compared to the median for 1987-2009.

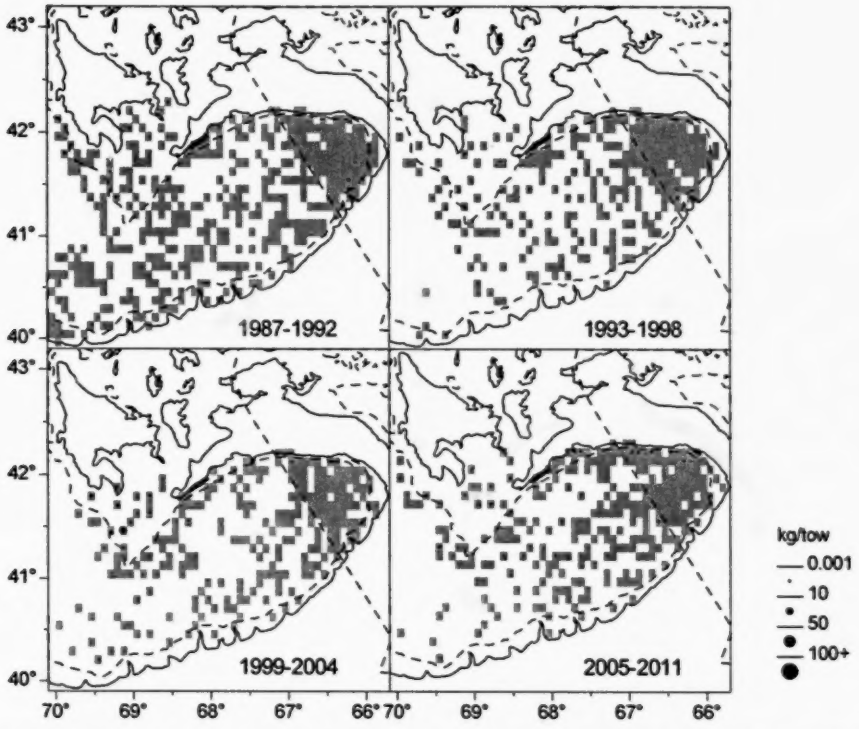


Figure 91. Distribution of smooth skate (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

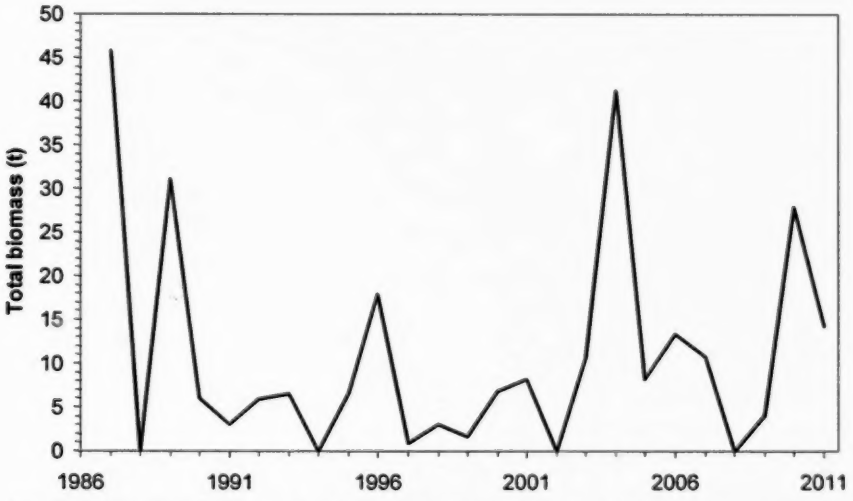


Figure 92. Total biomass estimates of smooth skate from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

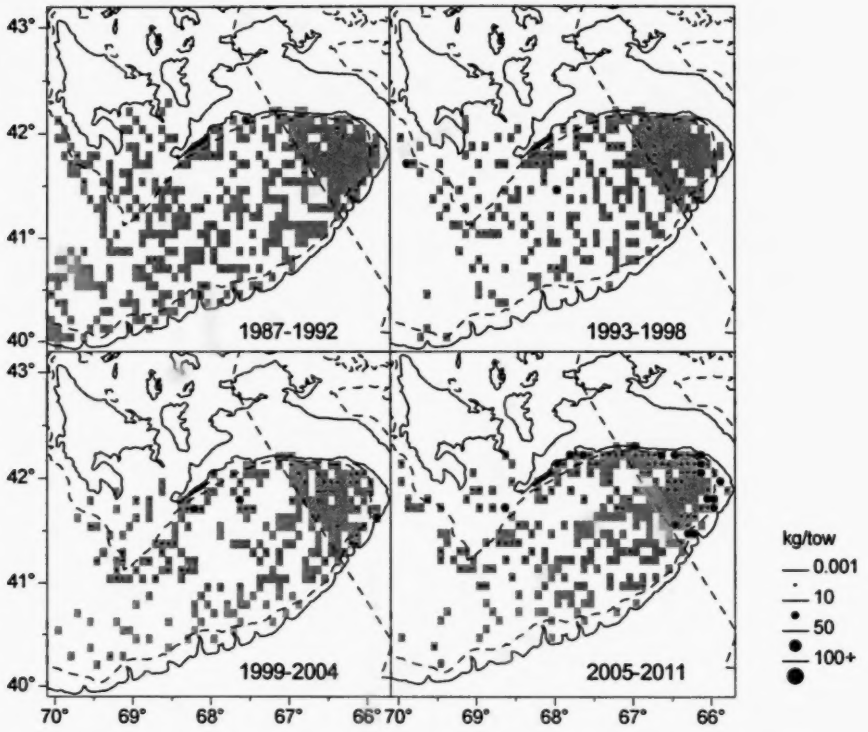


Figure 93. Distribution of American lobster (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

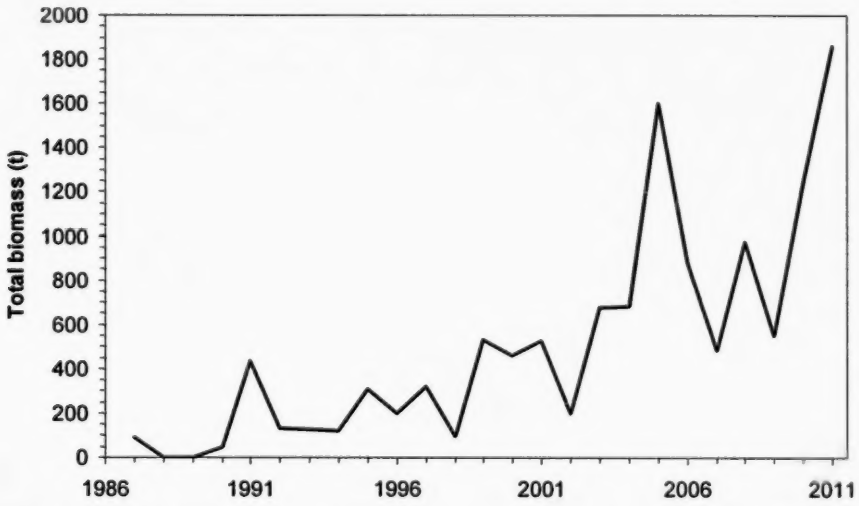


Figure 94. Total biomass estimates of American lobster from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

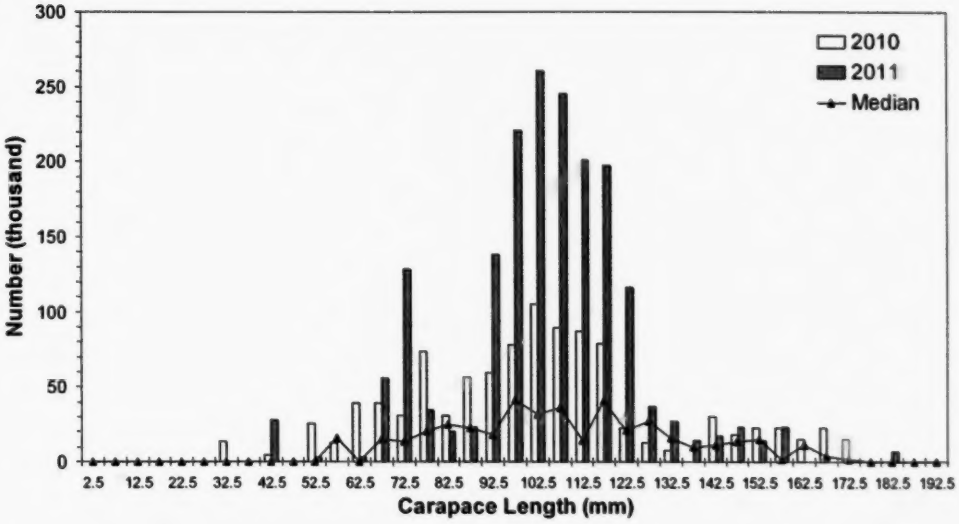


Figure 95. Length stratified total number (thousands) for American lobster from Georges Bank Survey strata 5Z1-5Z4 for 2010 and 2011 compared to the median for 2006-2009.

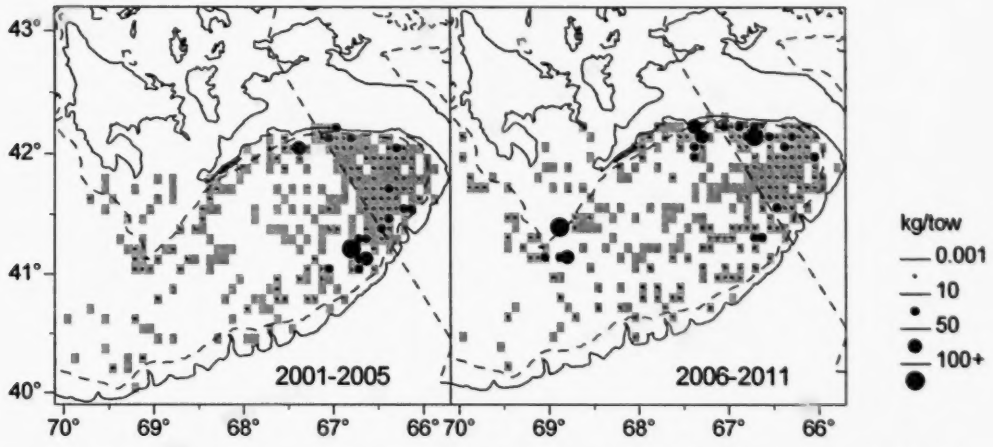


Figure 96. Distribution of sea scallop (5 or 6 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 2000-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary. Scallop catches were not recorded from 1987- 1999.

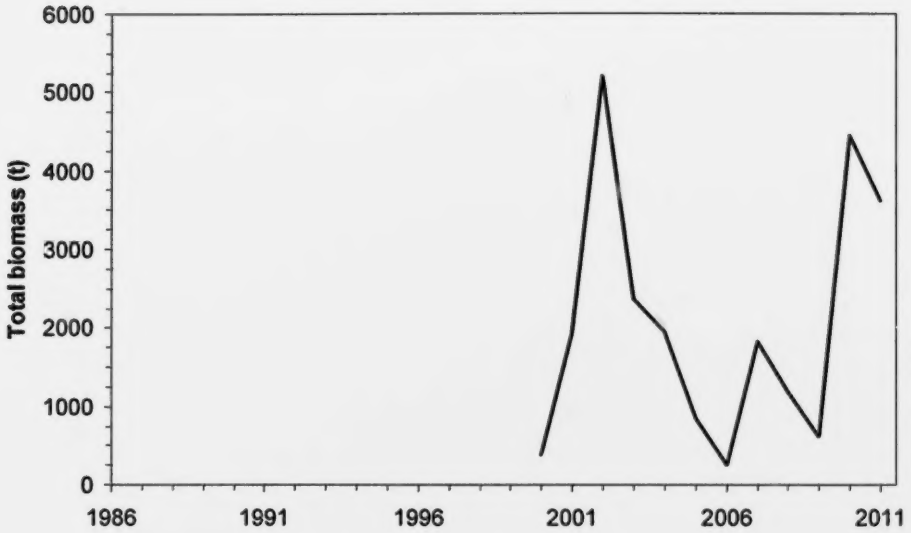


Figure 97. Total biomass estimates of sea scallops from Georges Bank survey strata 5Z1-5Z4, 2000-2011.

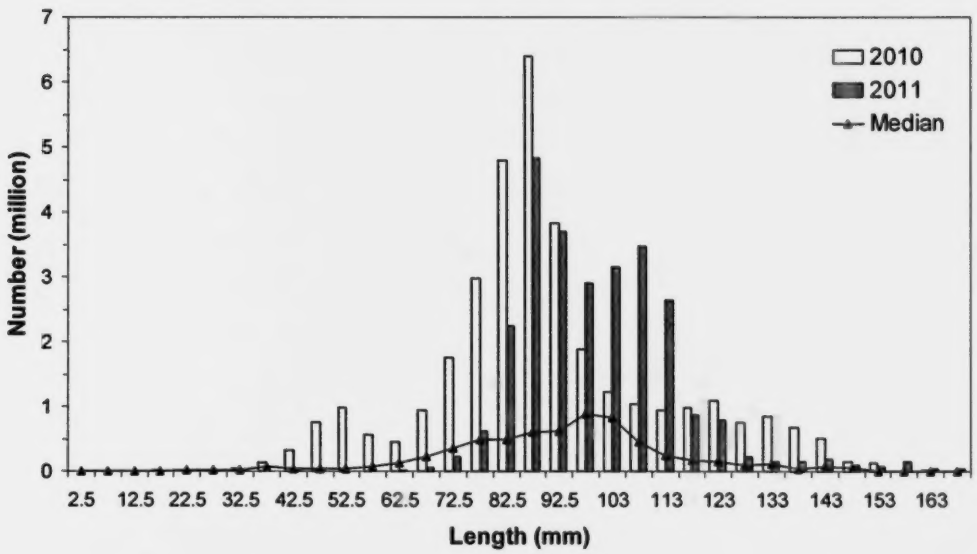


Figure 98. Length stratified total number (thousands) for sea scallops from Georges Bank Survey strata 5Z1-5Z4 for 2010 and 2011 compared to the median for 2006-2009.

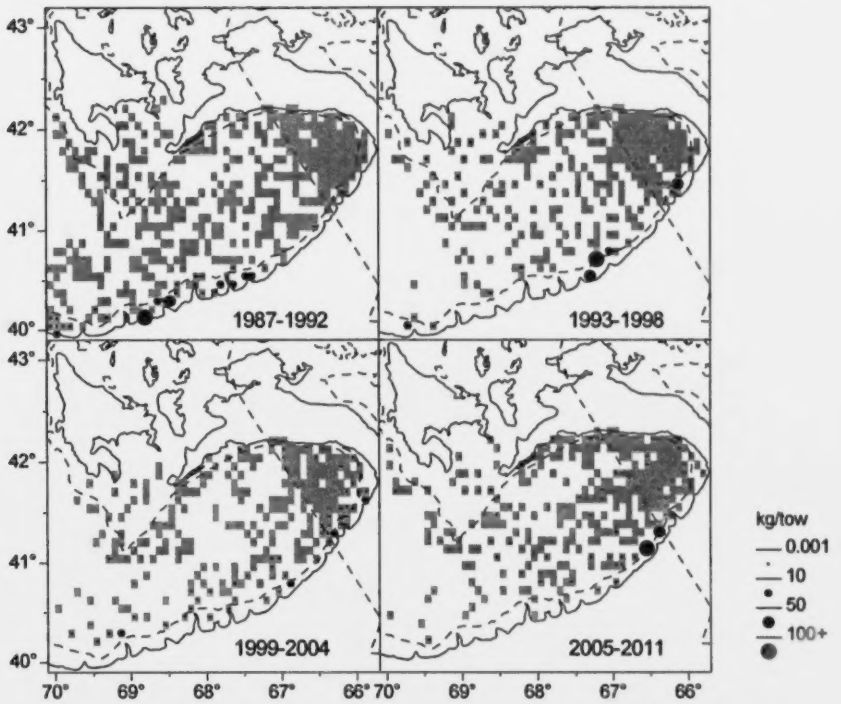


Figure 99. Distribution of shortfin squid (6 or 7 year average weight (kg)/tow aggregated by 5 minute squares) from the Georges Bank survey strata 5Z1-5Z8, 1987-2011. Grey shading indicates extent of area surveyed. The solid line indicates the international boundary.

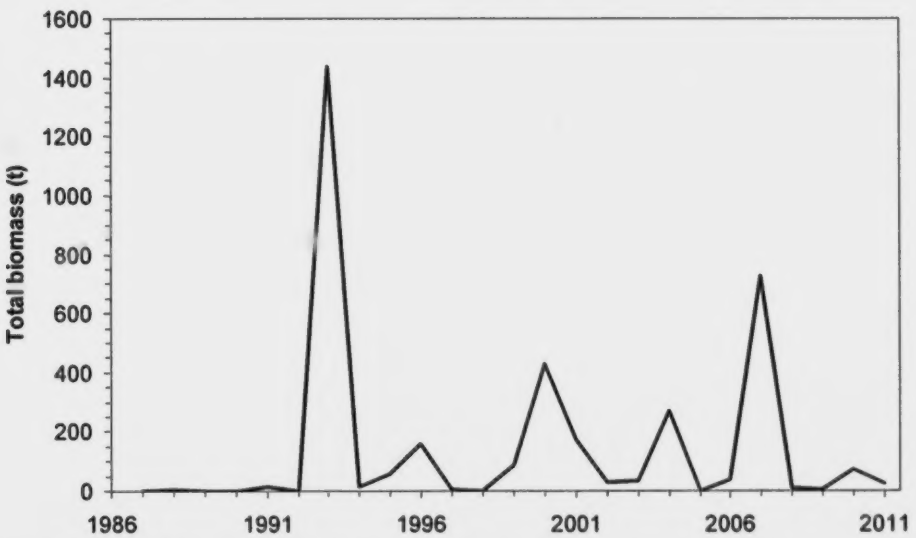


Figure 100. Total biomass estimates of shortfin squid from Georges Bank survey strata 5Z1-5Z4, 1987-2011.

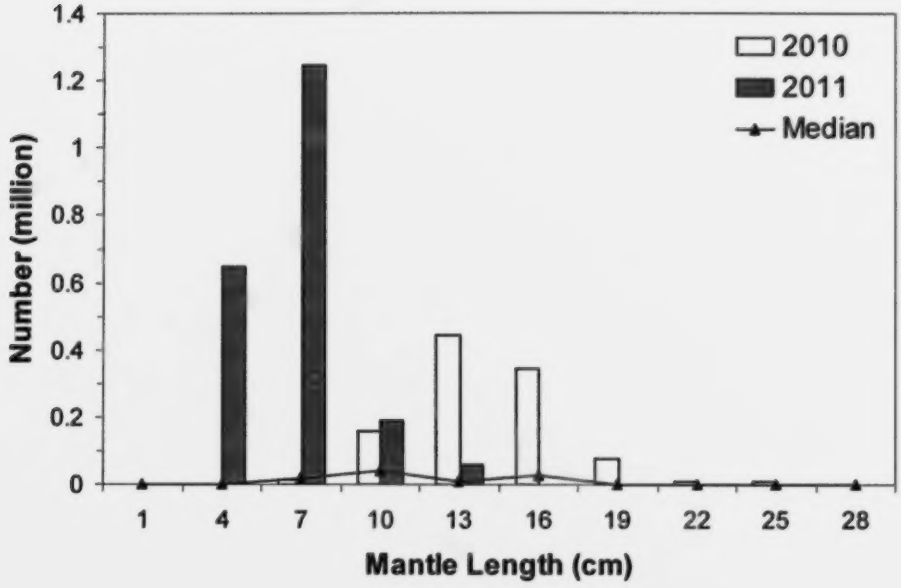


Figure 101. Length stratified total number (thousands) for shortfin squid from Georges Bank Survey strata 5Z1-5Z4 for 2010 and 2011 compared to the median for 1987-2009.

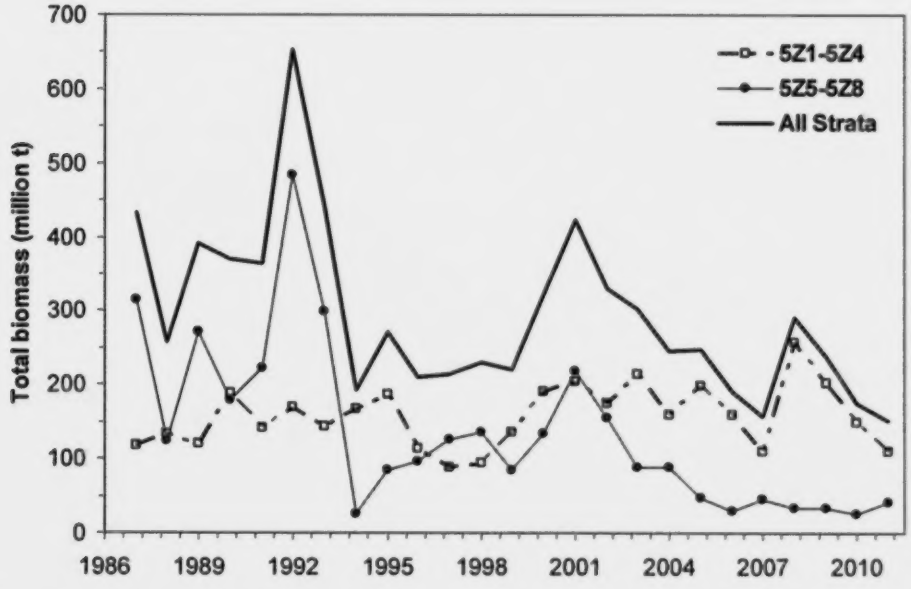


Figure 102. Estimated total biomass (all species) for strata 5Z1-5Z4, 5Z5-5Z8 and all strata combined from the Georges Bank survey, 1987-2011.

Appendix 1. Summary of average temperature, salinity and depth data by strata from the Georges Bank survey, 1987-2011.

		Temperature (°C)				Salinity (ppt)				Depth (m)			
Stratum	Year	Mean	Min	Max	n	Mean	Min	Max	n	Mean min	Mean max	Range	n
5Z1	1987	5.85	4.21	8.29	8	33.24	32.21	34.13	8	64	69	51 - 93	9
	1988	7.53	3.95	10.51	24	33.95	32.10	35.24	24	63	68	49 - 101	24
	1989	6.76	5.28	8.73	16	33.60	32.75	34.61	16	59	67	49 - 101	18
	1990	5.60	4.16	8.47	18	33.65	32.87	34.90	19	61	65	50 - 98	23
	1991	6.32	5.19	9.75	17	33.41	32.93	34.56	17	59	63	48 - 90	23
	1992	5.38	4.46	8.62	10	33.06	32.66	33.76	10	59	65	50 - 108	11
	1993	6.21	3.81	9.68	10	33.57	32.52	34.95	10	62	65	49 - 83	10
	1994	8.43	5.64	11.56	5	34.06	33.32	34.86	5	61	62	50 - 84	6
	1995	7.29	5.21	9.30	7	33.74	32.80	34.77	7	58	60	49 - 77	9
	1996	7.36	5.52	8.75	9	33.70	32.93	34.52	8	59	62	51 - 84	9
	1997	6.39	4.73	8.91	5	33.27	32.33	34.84	5	56	58	50 - 82	9
	1998	5.35	4.47	7.58	6	33.04	32.61	33.51	6	66	69	52 - 92	10
	1999	9.84	8.49	11.51	4	34.74	33.70	35.18	4	71	75	53 - 101	8
	2000	8.75	7.64	9.33	5	34.31	33.81	34.85	5	54	57	50 - 83	10
	2001	6.94	5.83	10.71	7	33.52	33.08	34.95	7	58	59	49 - 76	9
	2002	7.04	6.13	8.03	6	33.61	33.10	34.31	6	58	63	40 - 88	10
	2003	7.59	6.71	8.36	4	34.19	33.78	34.65	4	60	62	49 - 77	11
	2004	6.26	4.82	8.71	5	33.74	33.29	34.55	5	69	73	51 - 99	10
	2005	7.54	7.54	7.54	1	34.74	34.74	34.74	1	70	73	50 - 96	14
	2006	7.44	6.18	10.55	5	33.78	33.09	35.07	5	68	71	50 - 103	12
	2007	5.99	4.55	7.16	8	33.36	32.49	34.46	8	60	65	51 - 89	10
	2008	6.11	5.14	8.66	7	33.55	33.08	34.74	7	56	59	51 - 92	8
	2009	6.21	5.27	7.82	5	33.49	33.00	34.28	5	57	60	47 - 69	6
	2010	8.06	6.53	11.74	5	33.98	33.37	35.51	5	57	60	48 - 88	9
	2011	7.55	5.78	9.67	6	33.87	32.85	35.19	6	62	67	51 - 98	10

		Temperature (°C)				Salinity (ppt)				Depth (m)			
Stratum	Year	Mean	Min	Max	n	Mean	Min	Max	n	Mean min	Mean max	Range	n
5Z2	1987	4.07	3.21	4.50	7	32.75	32.45	32.86	7	42	43	34 - 47	7
	1988	4.21	3.37	5.14	27	32.68	32.34	33.41	27	42	44	33 - 52	28
	1989	4.69	4.11	6.57	23	32.83	32.65	33.48	23	42	44	32 - 52	25
	1990	4.76	4.50	5.16	15	33.28	33.16	33.40	18	39	42	31 - 50	22
	1991	5.43	5.01	6.87	23	33.06	32.84	33.83	23	40	43	28 - 52	25
	1992	4.49	4.12	4.88	29	32.60	32.42	32.78	29	42	44	32 - 51	32
	1993	3.59	2.97	4.79	35	32.44	32.18	32.95	35	42	44	29 - 53	36
	1994	5.00	4.34	6.49	22	33.06	32.81	33.56	22	42	43	29 - 51	24
	1995	5.05	4.30	6.41	28	32.80	32.52	33.24	27	41	43	30 - 51	32
	1996	5.08	4.34	6.42	33	32.77	32.41	33.42	30	43	44	32 - 54	33
	1997	4.72	4.57	4.86	9	32.35	32.30	32.38	9	43	45	31 - 52	32
	1998	4.83	3.42	5.84	7	32.56	32.45	32.71	7	42	44	31 - 51	37
	1999	5.76	4.79	7.90	11	32.77	32.38	33.48	11	43	44	31 - 51	31
	2000	5.89	5.16	7.07	10	33.06	32.73	33.45	10	43	45	33 - 52	35
	2001	5.70	5.35	6.87	18	32.99	32.78	33.48	18	42	43	31 - 50	33
	2002	5.61	5.16	6.00	17	32.94	32.72	33.09	17	43	45	32 - 51	34
	2003	4.84	2.85	6.81	10	32.94	32.24	33.66	10	41	43	33 - 64	37
	2004	3.64	3.44	4.01	9	32.83	32.71	33.00	9	44	47	32 - 62	35
	2005	3.91	3.28	4.40	3	32.38	32.12	32.68	3	38	41	21 - 50	48
	2006	5.43	5.20	6.00	12	32.78	32.67	33.01	12	41	43	33 - 51	39
	2007	4.33	3.96	4.72	12	32.41	32.22	32.61	12	41	43	30 - 51	35
	2008	4.74	4.26	5.05	11	32.95	32.76	33.08	11	41	43	32 - 50	26
	2009	4.91	4.48	6.67	10	32.97	32.69	34.03	10	42	45	31 - 53	19
	2010	5.58	5.23	6.32	13	32.91	32.77	33.19	13	41	43	31 - 50	23
	2011	5.16	4.59	5.84	16	32.62	32.33	32.93	16	43	44	31 - 50	35

Appendix 1 continued.

Stratum	Year	Temperature (°C)				Salinity (ppt)				Depth (m)			
		Mean	Min	Max	n	Mean	Min	Max	n	Mean min	Mean max	Range	n
5Z3	1987	3.96	3.74	4.60	7	33.00	32.71	33.18	6	31	37	17 - 95	7
	1988	4.33	3.95	4.72	15	32.71	32.56	32.84	14	29	32	17 - 49	16
	1989	4.39	3.82	6.62	12	33.01	32.74	33.79	12	34	35	16 - 96	12
	1990	4.59	4.17	5.17	12	33.24	33.01	33.49	12	33	36	13 - 96	14
	1991	5.21	4.62	6.13	13	33.02	32.76	33.39	13	32	34	18 - 92	13
	1992	4.18	4.01	4.43	9	32.62	32.46	32.79	9	36	38	18 - 97	11
	1993	3.47	3.26	3.72	11	32.55	32.30	32.73	11	26	29	18 - 39	11
	1994	4.35	3.96	4.89	9	32.88	32.76	32.96	9	30	31	15 - 53	9
	1995	5.41	4.67	5.99	11	33.13	32.83	33.32	11	26	27	19 - 35	11
	1996	4.96	4.54	5.86	11	32.83	32.53	33.14	11	40	42	17 - 90	14
	1997	5.33	4.63	8.04	6	32.62	32.22	34.24	6	35	37	19 - 96	11
	1998	5.00	4.85	5.15	3	32.37	32.25	32.45	3	26	29	18 - 39	16
	1999	5.45	5.28	5.69	4	32.62	32.46	32.99	4	39	41	29 - 83	10
	2000	5.56	4.83	6.87	7	33.26	32.91	33.67	7	40	41	19 - 96	15
	2001	5.41	5.09	5.92	6	33.02	32.90	33.08	6	35	37	18 - 90	9
	2002	5.76	5.48	6.10	3	32.94	32.86	33.00	3	27	29	17 - 35	5
	2003	3.82	2.88	5.79	7	33.03	32.30	33.41	7	33	35	18 - 97	15
	2004	4.39	3.69	5.90	5	33.26	32.92	33.74	5	32	35	20 - 80	11
	2005	4.70	3.70	7.39	4	32.93	32.29	34.69	4	38	41	18 - 101	25
	2006	5.48	4.72	7.31	4	33.14	32.74	34.03	4	39	41	25 - 96	14
	2007	4.51	4.43	4.58	2	32.92	32.84	33.01	2	28	31	16 - 62	11
	2008	5.63	4.80	7.70	4	33.34	32.89	34.35	4	36	37	20 - 96	11
	2009	5.11	4.82	5.67	4	33.10	32.98	33.33	4	32	34	18 - 65	12
	2010	5.01	4.38	6.08	6	32.78	32.50	33.16	6	35	38	16 - 98	15
	2011	5.79	5.17	8.28	10	32.98	32.60	34.13	10	40	43	19 - 98	14

Stratum	Year	Temperature (°C)				Salinity (ppt)				Depth (m)			
		Mean	Min	Max	n	Mean	Min	Max	n	Mean min	Mean max	Range	n
5Z4	1987	3.89	3.65	4.15	11	32.81	32.53	33.51	11	29	30	19 - 40	11
	1988	4.30	3.86	6.29	16	32.71	32.58	33.60	16	37	38	27 - 50	16
	1989	4.65	4.14	6.11	15	32.92	32.71	33.35	15	34	36	17 - 49	15
	1990	4.85	4.21	5.59	13	33.15	32.89	33.40	15	37	39	13 - 52	16
	1991	5.42	5.03	6.24	17	33.01	32.85	33.12	17	34	36	21 - 52	17
	1992	4.17	4.02	4.36	15	32.54	32.43	32.70	15	34	36	21 - 50	15
	1993	4.18	3.17	6.38	6	32.69	32.47	33.42	6	41	43	24 - 50	6
	1994	5.67	4.40	8.11	4	33.16	32.88	33.83	4	41	41	28 - 46	5
	1995	5.41	4.91	6.70	12	33.18	33.08	33.37	12	38	39	21 - 51	12
	1996	4.94	4.31	5.74	12	32.86	32.75	33.03	12	38	39	28 - 49	13
	1997	4.84	4.55	6.12	9	32.29	32.17	32.81	9	37	39	22 - 51	15
	1998	4.68	4.35	5.05	7	32.35	32.10	32.77	7	34	36	23 - 51	13
	1999	5.96	5.29	8.18	7	32.71	32.32	33.56	7	36	37	24 - 44	15
	2000	5.50	4.61	6.78	8	33.21	33.05	33.43	8	35	36	19 - 51	15
	2001	5.52	4.77	6.35	7	32.93	32.64	33.17	7	39	40	20 - 51	13
	2002	5.88	5.54	6.98	7	32.87	32.75	33.17	7	37	37	23 - 49	15
	2003	4.26	3.68	5.14	4	32.83	32.67	33.11	4	40	41	26 - 50	13
	2004	4.10	3.47	5.31	5	33.21	33.10	33.31	5	38	41	26 - 53	12
	2005	3.92	3.49	4.22	3	32.32	32.31	32.35	3	37	38	19 - 51	20
	2006	5.24	4.42	5.72	7	32.76	32.53	32.91	7	34	36	21 - 49	20
	2007	4.07	3.78	4.45	6	32.48	32.20	32.87	6	38	39	23 - 50	15
	2008	5.17	5.05	5.40	4	32.88	32.71	33.03	4	35	37	21 - 50	12
	2009	4.75	4.57	5.01	3	32.82	32.76	32.91	3	34	37	19 - 50	13
	2010	4.82	4.44	5.22	5	32.60	32.37	32.79	5	33	36	18 - 50	10
	2011	5.40	5.10	6.07	4	32.85	32.68	33.09	4	37	39	22 - 50	15

Appendix 1 continued.

Stratum	Year	Temperature (°C)				Salinity (ppt)				Depth (m)			
		Mean	Min	Max	n	Mean	Min	Max	n	Mean min	Mean max	Range	n
5Z5	1987	5.01	3.90	5.90	9	33.14	32.89	33.34	9	81	88	62 - 96	9
	1988	5.94	4.99	6.80	12	33.39	32.95	33.97	12	82	85	50 - 100	12
	1989	5.62	4.10	6.76	12	33.44	33.23	33.82	12	85	88	53 - 102	12
	1990	5.23	4.55	6.03	13	33.46	33.25	33.79	13	82	84	61 - 101	13
	1991	5.75	5.05	6.20	11	33.24	33.07	33.55	11	77	82	55 - 98	12
	1992	5.29	4.90	5.51	3	32.85	32.81	32.90	3	69	74	51 - 89	4
	1995	6.67	6.30	7.21	5	33.42	33.31	33.58	5	83	86	71 - 97	5
	1996	6.14	5.24	7.67	4	33.30	32.95	34.07	4	86	90	74 - 102	4
	1997	6.94	5.76	7.80	5	33.30	32.62	33.99	5	82	86	71 - 98	5
	1998	5.84	5.56	6.11	2	32.62	32.56	32.68	2	85	86	63 - 96	5
	1999	6.69	6.69	6.69	1	33.59	33.59	33.59	1	94	95	91 - 98	3
	2000	6.40	6.16	6.58	4	33.57	33.53	33.63	4	90	92	73 - 101	5
	2001	6.47	6.25	6.69	2	33.31	33.14	33.48	2	69	77	63 - 81	3
	2002	6.78	6.57	6.99	2	33.46	33.29	33.64	2	88	89	75 - 101	5
	2003	5.25	5.16	5.34	2	33.48	33.48	33.48	2	73	79	54 - 85	4
	2004	4.86	4.86	4.86	1	33.40	33.40	33.40	1	82	89	74 - 95	4
	2005	5.40	4.67	6.13	2	33.05	32.47	33.63	2	67	72	53 - 95	4
	2006												
	2007	6.85	6.85	6.85	1	33.52	33.52	33.52	1	67	81	67 - 81	1
	2008	5.00	4.93	5.06	2	33.14	33.14	33.15	2	77	79	68 - 87	2
	2009	4.90	4.86	4.94	2	33.04	32.98	33.11	2	69	72	55 - 83	5
	2010	5.92	5.92	5.92	1	33.05	33.05	33.05	1	91	94	88 - 97	3
	2011	7.65	7.61	7.70	2	33.48	33.43	33.53	2	87	89	76 - 96	5

Stratum	Year	Temperature (°C)				Salinity (ppt)				Depth (m)			
		Mean	Min	Max	n	Mean	Min	Max	n	Mean min	Mean max	Range	n
5Z6	1987	3.94	3.45	4.34	5	32.96	32.81	33.12	5	26	28	17 - 38	5
	1988	4.29	3.28	4.59	11	32.65	32.53	32.81	11	34	37	25 - 49	11
	1989	4.67	3.87	4.99	9	32.03	31.19	33.00	8	29	31	12 - 39	9
	1990	4.67	3.88	5.02	8	33.08	32.90	33.28	8	33	34	24 - 45	8
	1991	5.60	4.18	6.23	14	32.99	32.77	33.18	14	32	35	19 - 48	14
	1992	4.76	4.19	5.43	10	32.73	32.64	32.79	10	31	34	22 - 46	10
	1995	5.76	4.34	6.33	10	33.21	32.86	33.33	10	33	35	21 - 46	10
	1996	4.72	3.63	5.27	9	32.74	32.31	32.91	9	32	34	17 - 50	9
	1997	5.41	5.22	5.57	7	32.30	32.16	32.42	7	31	33	24 - 49	11
	1998	5.17	4.43	5.92	5	32.35	32.18	32.50	5	26	28	17 - 36	9
	1999	5.55	4.96	5.92	4	32.49	32.28	32.68	4	32	33	25 - 38	8
	2000	5.03	4.46	5.68	6	33.20	33.12	33.29	6	35	38	23 - 46	12
	2001	5.53	5.03	5.83	3	33.02	32.98	33.07	3	39	40	18 - 51	3
	2002	6.12	5.74	6.39	7	32.92	32.75	33.11	7	34	36	23 - 50	12
	2003	4.24	3.62	4.94	3	33.33	33.27	33.43	3	30	32	21 - 46	11
	2004	4.06	3.82	4.41	3	33.19	33.17	33.24	3	30	32	16 - 48	8
	2005	4.05	3.53	4.43	3	32.35	32.31	32.43	3	32	34	16 - 49	12
	2006									36	38	31 - 45	4
	2007	5.14	4.81	5.67	5	33.03	32.92	33.14	5	36	39	21 - 50	11
	2008	4.77	4.15	5.38	2	32.86	32.68	33.05	2	32	34	24 - 50	6
	2009	5.26	5.26	5.26	1	32.89	32.89	32.89	1	30	32	15 - 46	9
	2010												
	2011	5.13	5.12	5.13	2	32.68	32.51	32.84	2	31	33	22 - 45	10

Appendix 1 continued.

Stratum	Year	Temperature (°C)				Salinity (ppt)				Depth (m)			
		Mean	Min	Max	n	Mean	Min	Max	n	Mean min	Mean max	Range	n
5Z7	1987	4.08	3.81	4.42	12	32.98	32.75	33.22	12	32	33	18 - 44	12
	1988	4.34	3.21	6.35	14	32.68	32.34	33.33	14	33	34	13 - 47	15
	1989	4.85	4.00	7.49	16	32.95	32.71	33.69	16	34	37	23 - 50	16
	1990	4.93	3.73	7.22	17	33.15	32.86	33.83	17	32	34	15 - 49	17
	1991	5.81	3.96	6.87	16	32.96	32.80	33.16	16	35	37	20 - 50	18
	1992	4.61	4.45	5.05	5	32.64	32.52	32.73	5	29	30	24 - 39	5
	1995	5.90	5.18	6.42	4	33.17	33.12	33.22	4	35	36	34 - 37	4
	1996	4.72	4.20	5.04	3	32.80	32.76	32.84	3	34	34	27 - 39	3
	1997	5.71	5.55	5.86	3	32.21	32.13	32.27	3	38	40	27 - 49	4
	1998	4.35	4.32	4.37	2	32.44	32.35	32.53	2	34	37	25 - 49	4
	1999	6.79	5.59	7.90	4	32.86	32.53	33.15	4	40	41	32 - 48	4
	2000	4.95	4.75	5.18	3	33.10	33.04	33.15	3	34	35	27 - 50	5
	2001	6.05	3.98	8.11	2	33.16	32.72	33.60	2	41	42	31 - 50	3
	2002	5.97	5.55	6.38	2	32.89	32.84	32.95	2	37	38	24 - 45	5
	2003	4.10	3.69	4.51	2	33.34	33.33	33.35	2	36	37	26 - 46	4
	2004	3.58	3.58	3.58	1	33.12	33.12	33.12	1	42	44	37 - 50	3
	2005	4.24	4.08	4.35	3	32.35	32.21	32.55	3	35	37	25 - 47	5
	2006									22	26	22 - 26	1
	2007	4.99	4.72	5.28	3	32.75	32.65	32.87	3	38	40	32 - 46	5
	2008	5.74	4.79	6.68	2	33.00	32.83	33.18	2	34	35	29 - 39	2
	2009	4.99	4.46	5.30	3	32.76	32.75	32.78	3	38	40	28 - 50	4
	2010												
	2011	5.32	5.24	5.40	2	32.81	32.60	33.02	2	32	36	22 - 43	5

Stratum	Year	Temperature (°C)				Salinity (ppt)				Depth (m)			
		Mean	Min	Max	n	Mean	Min	Max	n	Mean min	Mean max	Range	n
5Z8	1987	8.16	3.66	12.12	8	34.12	32.52	35.46	8	62	65	52 - 94	8
	1988	9.53	4.44	10.85	10	34.54	32.66	35.06	10	62	65	52 - 78	10
	1989	11.40	10.48	11.82	9	34.90	33.23	35.35	9	67	70	52 - 89	9
	1990	9.46	5.55	11.81	10	34.52	33.25	35.29	10	64	70	50 - 96	10
	1991	9.45	5.90	13.67	10	34.28	33.13	35.62	10	64	66	50 - 89	10
	1992	9.63	8.26	10.44	3	34.72	34.32	35.15	3	78	83	53 - 117	3
	1993	9.94	9.49	10.39	2	34.55	34.38	34.72	2	60	61	59 - 62	2
	1994									53	55	53 - 55	1
	1995	11.67	9.46	13.87	2	34.90	34.14	35.66	2	66	67	52 - 81	2
	1996	7.65	7.65	7.65	1	33.93	33.93	33.93	1	67	73	67 - 73	1
	1997	10.44	7.53	13.38	3	34.22	33.23	35.28	3	54	57	50 - 61	3
	1998									53	55	53 - 56	2
	1999	12.05	11.05	12.90	3	34.95	34.68	35.30	3	71	73	60 - 85	3
	2000	10.73	8.86	12.24	3	34.87	34.35	35.41	3	63	64	55 - 79	3
	2001	11.58	10.77	12.02	3	35.05	34.66	35.28	3	73	78	60 - 87	3
	2002	9.43	6.95	10.72	3	34.32	33.57	34.76	3	60	61	51 - 71	3
	2003	7.87	5.99	9.74	2	34.23	33.40	35.05	2	66	68	55 - 88	3
	2004	10.59	8.50	12.67	2	35.06	34.55	35.56	2	71	86	67 - 92	2
	2005	11.08	11.08	11.08	1	35.12	35.12	35.12	1	71	75	59 - 83	3
	2006									63	67	58 - 75	2
	2008	11.86	11.86	11.86	1	35.11	35.11	35.11	1	84	88	74 - 95	2
	2009												
	2010	11.45	11.45	11.45	1	34.97	34.97	34.97	1	54	56	49 - 65	3
	2011	7.87	7.87	7.87	1	33.80	33.80	33.80	1	61	64	53 - 77	3